ADA

Evaluation of Korean-Manufactured Non-Tactical Vehicle JP-8 Conversion Demonstration Conducted by the 19th Theatre Area Army Command, Korea

INTERIM REPORT
TFLRF No. 352

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A C of S G-4
Seoul, South Korea

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13. ABSTRACT (Maximum 200 words)

TFLRF staff provided technical support to an in-progress non-tactical vehicle JP-8 fuel demonstration program. The fleets had been operating on JP-8 fuel at two U.S. Army installaitons in Korea for seven months. The fuel conversion plan and fleet test parameters were designed and coordinated by the transportation officer of the 19th Theatre Area Army Command G-4. Therefore, the TFLRF team's main objectives were to evaluate the on-going JP-8 conversion demonstration and assess the feasibility of using JP-8 fuel in lieu of diesel fuel in Korean-manufactured NTVs using the data and information available at the test sites. The data revealed that the Korean-manufactured NTVs operated on JP-8 fuel for a period of 12 months and accumulated in excess of one million kilometers without experiencing fuel-related operational problems.

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FOREWORD/ACKNOWLEDGMENTS

This work was performed by the U.S. Army TARDEC Fuels and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, Texas, during the period June 1999 through September 2000 under Contract No. DAAK70-92-C-0059. The work was funded and administered by the U.S. Army Tank-Automotive RD&E Center, Petroleum and Water Business Area, Warren, Michigan. Mr. Luis Villahermosa (AMSTA TR-D/210) served as the TARDEC contracting officer's representative and project technical monitor.

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The authors would like to recognize the technical support provided by Mr. E.A. Frame of TFLRF. A special thanks is given to Ms. Wendy Mills of TFLRF for her assistance in the preparation and editing of this report.

EXECUTIVE SUMMARY

Problem: DOD Directive 4140.25 prescribes using a single kerosene-type fuel (JP-8) as the primary fuel support for land-based air and ground forces in overseas theaters. The Army's tactical bulk fuel distribution system can only distribute JP-8 fuel.

Objective: The TFLRF team's main objective was to assess the feasibility of using JP-8 fuel in lieu of diesel fuel in Korean-manufactured non-tactical vehicles (NTVs) using the data and information available at the test sites.

Importance of Project: The use of JP-8 fuel in non-tactical vehicles (NTV) will align the Eighth U.S. Army (EUSA) with the Single Fuel Forward Concept and allow a seamless transition from armistice to war with respect to bulk fuel distribution and improve EUSA's defensive posture.

Technical Approach: Two TFLRF staff members traveled to the two locations in Korea where the NTVs were being tested on two separate occasions. Vehicle usage data and status reports on kilometers driven and fuel consumed were collected, and fuel samples were obtained from selected NTVs to encompass a thorough sampling of the different models and makes. The samples were shipped to TFLRF for chemical analysis. Injection pumps representing a cross-section of Korean-manufactured NTVs were removed from selected vehicles and shipped to TFLRF for tear-down analysis.

Accomplishments: Data extrapolation revealed that the Korean-manufactured NTVs accumulated in excess of one-million kilometers of operation on JP-8 fuel during a period of 12 months without experiencing fuel-related operational problems. Laboratory fuel sample analysis confirmed that the JP-8 fuel used for the conversion test was in compliance with specification MIL-T-83133 for Fuel, Aviation Turbine Engine. Laboratory fuel sample analysis confirmed that the lubricity of the JP-8 fuel used in the conversion test was lower than the diesel samples; but it was not in the critical range as specified in the JP-8 Compendium concerning the Army's recommended lubricity requirements. Tear-down analysis of the injection pumps revealed that the higher than normal wear observed in the pumps was the result of conditions other than diesel or JP-8 fuel. A briefing on the findings and recommendations was presented to the G-4 office petroleum officers at the 19th Theatre Area Army Command and the Eight U.S. Army Command.

Military Impact: Non-tactical Korean-manufactured vehicles, including emergency-designated vehicles, can operate satisfactorily while using MIL-T-83133 Fuel, Aviation Turbine JP-8.

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LIST OF ACRONYMS AND ABBREVIATIONS

DoD	Department of Defense
NTV	Non-Tactical Vehicle
EUSA	Eighth US Army
ACofS	Assistant Chief of Staff
POL	Petroleum, Oils & Lubricants
TAACOM	Theatre Area Army Command
TARDEC	Tank-automotive Research, Development and Engineering Center
NCOIC	Non-Commissioned Officer in Charge
DESC	Defense Engergy Supply Center
TFLRF	TARDEC Fuels and Lubricants Research Facility
SwRI	Southwest Research Institute
TMP	Transportation Motor Pool

I. BACKGROUND

DOD Directive 4140.25 (1)* prescribes using a single kerosene-type fuel (JP-8) (2) as the primary fuel support for land-based air and ground forces in overseas theaters.(3) The Army's tactical bulk fuel distribution system can only distribute JP-8 fuel. Therefore, the use of JP-8 fuel in non-tactical vehicles (NTV) will align the Eighth U.S. Army (EUSA) with the Single Fuel Forward Concept and allow a seamless transition from armistice to war with respect to bulk fuel distribution and improve EUSA's defensive posture.

II. INTRODUCTION

The ACofS G-4, 19th Theatre Area Army Command (TAACOM) initiated a JP-8 fuel-conversion demonstration test involving 101 Korean-manufactured, non-tactical vehicles (NTV) to determine the feasibility of using JP-8 aviation turbine fuel in lieu of diesel fuel. The demonstration test was originally scheduled for 01 December 1998 through 31 March 1999. The POL Officer of the ACofS G-4, Eighth U.S. Army (EUSA) coordinated with the 19th TAACOM to extend the test through 31 July1999 to assess the NTV's performance with JP-8 during high-temperature operation. EUSA also coordinated with the TARDEC Petroleum and Water Business Area Fuels and Lubricants Team to provide technical support and evaluate the results of the ongoing demonstration test and to assess JP-8's suitability for use in Korean-manufactured diesel-burning NTVs. TARDEC acquired funding from the Defense Energy Supply Center (DESC) and EUSA and tasked the TARDEC Fuels and Lubricants Research Facility (TFLRF) at Southwest Research Institute (SwRI) in San Antonio, TX to evaluate the JP-8 conversion test.

III. OBJECTIVE

As part of this program, TFLRF provided technical support to an in-progress NTV/JP-8 fuel conversion test fleet. The fleet had been operating on JP-8 fuel at two U.S. Army installations in South Korea for

*** Numbers in parentheses represent references at the end of the document.**

seven months. The fuel conversion plan and fleet test parameters were designed and coordinated by the transportation officer of the 19th TAACOM G-4. Therefore, the TFLRF team's main objective was to assess the feasibility of using JP-8 fuel in lieu of diesel fuel in Korean-manufactured NTVs using the data and information available at the test sites.

IV. APPROACH

A plan was formulated for two TFLRF staff members to travel to South Korea and meet with 19th TAACOM, EUSA personnel, and representatives from the major Korean automobile manufacturers to discuss the use of JP-8 in Korean-manufactured NTVs. Visits were planned for the two locations where the NTVs were being tested. Fuel samples would be obtained from selected NTVs to encompass a thorough sampling of the different models and makes. Vehicle usage data and status reports on kilometers driven and fuel consumed would be obtained and analyzed. The samples would be shipped to TFLRF for chemical analysis of fuel properties and other parameters. Failed fuel-wetted components (injectors, injection pumps, filters, etc.), if any, would be collected and shipped to TFLRF for failure analysis. A report would be generated based on the findings.

V. TEST FLEETS AND SITE VISITS

The first site visit was in July 1999. Two TFLRF staff members traveled to South Korea to meet with personnel from the 19th TAACOM ACofS G-4 Transportation, EUSA ACofS G-4 Transportation, EUSA ACofS, G-4 POL, and representatives of the three Korean auto manufacturers. The purpose of this meeting was to present a briefing on the Army JP-8 program and to discuss the use of JP-8 fuel in Korean-manufactured NTVs used throughout EUSA. The meeting was held at the EUSA ACofS G-4 transportation office. The EUSA transportation officer presented the TFLRF members with letters from Hyundai, Daewoo, and KIA auto companies, who collectively stated that warranties on Korean-manufactured vehicles would be voided with the use of JP-8. However, representatives of these companies at the meeting were asked to assess injection pump durability with JP-8; they agreed that new fuel injection pumps should provide in excess of 100,000 kilometers of problem-free service with the use of JP-8 fuel.

TFLRF staff members visited the motor pools at Camp Henry, Taegu and Camp Long, Wonju, obtaining JP-8 and diesel samples from vehicle fuel tanks and bulk dispensing facilities. The samples were shipped to TFLRF for analysis. Since there were no failed components at Camps Henry or Long, four injection pumps from the Camp Henry TMP motor pool and two pumps from the Camp Long TMP motor pool were removed from normal operating vehicles and shipped to TFLRF for calibration runs and tear-down analysis. These results are discussed later in this report. Four injection pumps were received from Camp Henry; but no injection pumps were received from Camp Long.

A. Camp Henry, Taegu, South Korea

TFLRF staff visited Camp Henry in Teagu, South Korea and met with the 19th TAACOM Transportation Officer, 20th Support Group Transportation Officer, and the Transportation Motor Pool (TMP) NCOIC to discuss vehicle performance at the start and during the JP-8 conversion test. The following topics were discussed: filter replacements if any, fuel-wetted component replacements, loss of power, idle quality, and hard start problems. Everyone stated that the fleet had operated virtually trouble-free except for reported power loss complaints on the 25 and 45-passenger buses. One bus in particular (T203) experienced severe power loss. Motor pool personnel stated that they had replaced fuel filters and cleaned the fuel lines, but no improvement was observed. TFLRF staff members requested that the injection pump for bus T-203 be included in the four scheduled for shipment to TFLRF. No other fuel filter replacements or fuel injection pump failures were reported throughout the test.

Table 1 presents the total number of Korean-manufactured vehicles, number of vehicles sampled, vehicle type, number of cylinders, injection pump type, and vehicle manufacturer in the test program at Camp Henry.

TABLE 1. Korean Manufactured Vehicles at Camp Henry					
Number Of Vehicles	Number Sampled	Vehicle Type	Number Of Cylinders	Injection Pump Type	Vehicle Manufacturer
14	7	Truck, Cargo 1-ton 4X2	4	Distributor	KIA, Hyundai,
5	3	Truck, Carryall 9 Pass 1-ton	4	Distributor	KIA, Hyundai, Ssanyong
1	1	Truck, Fuel Tank 1200-gallon	6	In-Line	Daewoo
1	1	Truck, Tractor 5-ton 6X4	6	In-Line	Daewoo
10	4	Truck, Utility ½ton 4X4	4	Distributor	Hyundai, Ssanyong
11	6	Truck, Maintenance ¾-ton 4X2	4	Distributor	KIA, Hyundai
2	1	Bus, Pax 25 Passenger	6	In-Line	Hyundai
4	3	Bus, Pax 45 Passenger	6	In-Line	Daewoo

Figures 1 through 8 show the different types of vehicles listed in Table 1.

Samples were obtained from 26 of 51 vehicles, one-each nozzle sample from the JP-8 dispensing pump, and one-each nozzle sample from the diesel fuel tanker.

The bulk JP-8 and diesel fuel storage units are located at Camp Walker, a small military post approximately six miles from Camp Henry. The JP-8 is stored in a 20,000-galon underground tank and is nozzle dispensed as shown in Figure 9. The diesel fuel is stored and dispensed from a 1,200-gallon refueler as shown in Figure 10. All vehicles are fueled at Camp Walker. Nozzle samples were obtained from the JP-8 dispensing pump and the diesel tanker then shipped to TFLRF for analysis.

Table 2 presents the identification number, vehicle type, model year, JP-8 test-starting kilometers, kilometers at time of sampling, and total kilometers at the time of sampling on JP-8 from the NTV vehicles at Camp Henry. This information (as of 10 July 1999) is the only usage data provided by the TMP at Camp Henry.

Figure 1. 1-ton Cargo Truck, 4x2

Figure 2. 9-passenger 1-ton Carryall Truck

Figure 3. 1,200-gallon Fuel Tank Truck

Figure 4. 5-ton Tractor Truck, 6x4

Figure 5. 1/2-ton Utility Truck, 4x4

Figure 6. 3/4-ton Maintenance Truck, 4x2

Figure 7. 25-passenger Bus

Figure 8. 45-passenger Bus

Figure 9. JP-8 Fueling Facility

Figure 10. 1,200-gallon Diesel Refueler

TABLE 2. Vehicles Sampled at Camp Henry					
ID Number	Vehicle Type	Model Year	Starting Test Km	Km On Date Of Sampling	Total Km On JP-8
T-36	Truck, Cargo 1 Ton	96	26,263	33,148	6,885
T-38	Truck, Cargo 1 Ton	96	22,787	25,739	2,952
T-42	Truck, Cargo 1 Ton	96	30,733	41,148	10,415
T-47	Truck, Cargo 1 Ton	97	12,828	14,831	2,003
T-51	Truck, Cargo 1 Ton	95	26,090	30,369	4,279
T-54	Truck, Cargo 1 Ton	92	93,678	97,794	4,116
T-55	Truck, Cargo 1 Ton	92	80,090	88,272	8,182
T-79	Truck, Carryall 1 Ton	94	50,455	55,638	5,183
T-89	Truck, Carryall 1 Ton	96	29,901	31,639	1,738
T-96	Truck, Carryall 1 Ton	92	70,202	72,223	2,021
T-126	Truck, Fuel 1,200 Gallon	98	1,183	1,562	379
T-145	Truck, Tractor 5 Ton	95	44,131	45,605	1,474
T-151	Truck, Utility ½ Ton	92	25,530	27,842	2,312
T-152	Truck, Utility ½ Ton	92	41,074	50,080	9,006
T-166	Truck, Utility ½ Ton	95	64,032	64,833	801
T-182	Truck, Utility ½ Ton	96	26,942	33,150	6,208
T-203	Bus, 45 Passenger	96	34,321	50,662	16,341
T-206	Bus, 45 Passenger	96	60,565	89,219	28,654
T-232	Bus, 25 Passenger	94	115,114	120,006	4,892
T-239	Bus, 45 Passenger	96	73,965	100,858	26,893
T-402	Truck, Maintenance ¾ Ton	92	32,074	35,407	3,333
T-403	Truck, Maintenance ¾ Ton	92	36,190	38,455	2,265
T-404	Truck, Maintenance ¾ Ton	92	34,156	36,803	2,647
T-409	Truck, Maintenance ¾ Ton	92	30,029	31,405	1,376
T-413	Truck, Maintenance ¾ Ton	92	32,231	34,849	2,618
T-416	Truck, Maintenance ¾ Ton	95	36,450	40,450	4,000

B. Camp Long, Wonju, Korea

TFLRF staff met with the NCOIC, TMP Motor Pool in Camp Long in Wonju, Korea to coordinate the sampling schedule of Korean-manufactured NTV vehicles on the JP-8 fleet test and to discuss test vehicle performance during the conversion test. The NCOIC stated categorically that none of the vehicles in the program experienced any JP-8 related problems at any time during the fleet test period. He stated that a fuel injection pump was replaced on a 1-ton carry all truck; however, the vehicle had 110,792 kilometers when converted to JP-8. Because of the high number of kilometers, he did not consider JP-8 the problem. Also, problems were reported at the start of the test on a Grace van, a Galloper utility vehicle, and a 1-ton cargo truck. The following corrective actions were taken: cleaned fuel tanks and lines, and replaced filters and glow plugs. The motor sergeant did not consider these problems JP-8 related. He was very satisfied with the vehicles' performance with JP-8 fuel. It should be noted that SFC Mills became familiar with JP-8 while stationed at Ft. Stewart, GA during its conversion to JP-8 fuel.

Table 3 presents the total number of Korean-manufactured vehicles, number of vehicles sampled, vehicle type, number of cylinders, injection pump type, and vehicle manufacturer in the test program at Camp Long. Figures 11 through 24 show the different types of vehicles listed in Table 3.

TABLE 3. Korean Manufactured Vehicles at Camp Long

Number Of Vehicles	Number Sampled	Vehicle Type	Number Of Cylinders	Injection Pump Type	Vehicle Manufacturer
11	5	Truck, Utility ½-ton 4X4	4	Distributor	Hyundai, Ssayong
12	7	Truck, Cargo 1-ton 4x2	4	Distributor	KIA
1	1	Truck, Maintenance ¾-ton	4	Distributor	KIA
7	3	Truck, Carryall 9 Pass 1-ton	4	Distributor	Hyundai
2	0	Truck. Panel 6 Pass	4	Distributor	Hyundai
2	2	Truck, Van 5 Ton	6	In-Line	KIA
2	1	Truck, Stake 5 Ton	6	In-Line	KIA
1	1	Truck, Modified ¾ Ton	4	Distributor	KIA
1	0	Truck, Tank 1,200 gallons	6	In-Line	Daewoo
1	1	Truck, Dump 15 Ton	6	In-Line	Hyundai
1	0	Truck, Dump 8 Ton	6	In-Line	Hyundai
1	1	Truck, Wrecker 5 Ton	6	In-Line	Hyundai
1	1	Truck, Wrecker 2 ½ Ton	6	In-Line	KIA
1	1	Truck, Tractor 5 Ton	6	In-Line	Hyundai
2	1	Bus, 25 Passenger	6	In-Line	Hyundai
2	2	Bus, 45 Passenger	6	In-Line	Daewoo

Figure 11. 1/2-ton Utility Truck, 4x4

Figure 12. 1-ton Cargo Truck, 4x2

Figure 13. 3/4-ton Maintenance Truck

Figure 14. 9-passenger 1-ton Carryall Truck

Figure 15. 5-ton Van Truck

Figure 16. 5-ton Cargo Truck

Figure 17. Modified 3/4-ton Truck

Figure 18. 1,200-gallon Water Tank Truck

Figure 19. 15-ton Dump Truck

Figure 20. 5-ton Wrecker Truck

Figure 21. 2 1/2-ton Wrecker Truck

Figure 22. 5-ton Tractor Truck

Figure 23. 25-passenger Bus

Figure 24. 45-passenger Bus

Samples were obtained from 27 of 50 vehicles, and one-each nozzle from the JP-8 dispensing pump. The fuel samples were shipped via Federal Express from Suwon, Korea on 16 July 1999 to TFLRF for analysis. The bulk JP-8 fuel is stored and dispensed at Camp Long as shown in Figures 25 and 26. The JP-8 is stored in two 10,000-gallon, above-ground tanks, while the diesel fuel is stored in a 20,000-gallon underground tank at Camp Eagle Point, a small military post located approximately 15 miles from Camp Long. The vehicles on the JP-8 fleet test are fueled at Camp Long, and vehicles utilizing diesel fuel are fueled at Camp Eagle Point.

Table 4 shows the test NTVs converted to JP-8 at Camp Long. An asterisk denotes vehicles sampled during the initial visit in July 1999. The record clerk was hospitalized during the initial visit in July; therefore vehicle usage data were not available at the time of sampling and were not provided until October 1999.

Figure 25. 10,000-gallon JP-8 Storage Tank

Figure 26. JP-8 Dispensing Pump

For reasons unknown, three sampled vehicles do not appear in the above table: W-024, 98 Truck Utility 4X4; W-093, 98 Truck Carryall 4X2; and W-150, 92 Truck Dump 15 ton 6X4.

A subsequent trip was made to Korea in December 1999 to brief the EUSA and the 19th TAACOM G-4 on the results of fuel and injection pump calibration and tear-down analyses. Visits were also made to Camps Henry and Long to sample fire trucks and ambulance emergency vehicles converted to JP-8 fuel.

C. Emergency Vehicles

Emergency vehicles at Camps Henry and Long were converted during September 1999. There were no records available to indicate the odometer readings at the time of conversion. Since usage on the emergency vehicles for the most part is minimal compared to the rest of the fleet, it was visually determined that the majority of the samples obtained had a commingled mixture of diesel and JP-8 fuels; consequently, no analyses were performed on these samples. Table 5 presents emergency vehicles assigned to and sampled at Camps Henry and Long. Vehicle identification numbers preceded with the letter "T" are from Camp Henry and those with the letter "W" are from Camp Long. Figures 27-34 show the emergency vehicles listed in Table 5.

TABLE 4. Vehicles Converted to JP-8 at Camp Long					
ID Number	**Vehicle Type**	**Model Year**	**Starting Test Km**	**Km as of 30 Sep 99**	**Total Km On JP-8**
W-013	Truck, Utility ½ ton	97	53,899	81,613	27,714
W-014	Truck, Utility ½ ton	97	36,662	49,429	12,767
W-015*	Truck, Utility ½ ton	96	97,032	114,188	17,156
W-017*	Truck, Utility ½ ton	96	53,779	60,617	6,838
W-018*	Truck, Utility ½ ton	95	99,590	112,523	12,933
W-019*	Truck, Utility ½ ton	95	78,825	100,348	21,523
W-021	Truck, Utility ½ ton	92	55,561	69,868	14,307
W-022	Truck, Utility ½ ton	95	123,539	144,857	21,318
W-023	Truck, Utility ½ ton	92	67,720	94,653	26,933
W-025	Truck, Utility ½ ton	95	66,649	74,383	7,734
W-030	Truck, Utility ½ ton	95	142,624	165,343	22,719
W-034*	Truck, Cargo 1 ton	95	16,286	23,761	7,475
W-035	Truck, Cargo 1 ton	95	18,410	58,137	39,727
W-036*	Truck, Cargo 1 ton	96	69,980	87,106	17.126
W-037	Truck, Cargo 1 ton	96	50,185	61,189	28,139
W-038	Truck, Cargo 1 ton	96	74,813	95,287	20,474
W-039	Truck, Cargo 1 ton	96	88,362	88,362	0
W-040	Truck, Cargo 1 ton	96	14,486	21,182	6,696
W-041	Truck, Cargo 1 ton	96	41,960	65,229	23,269
W-042*	Truck, Cargo 1 ton	96	54,219	65,487	11,268
W-043*	Truck, Cargo 1 ton	96	35,477	45,783	10,306
W-044	Truck, Cargo 1 ton	96	38,233	50,901	12,668
W-045*	Truck, Cargo 1 ton	96	46,725	68,611	21,866
W-046*	Truck, Cargo 1 ton	96	50,565	55,918	5,353
W-047	Truck, Cargo 1 ton	97	12,794	16,496	3,702
W-052*	Truck, Maint ¾ ton	97	17,462	23,961	6,499
W-080	Truck, Carryall 1 ton	94	147,292	166,765	19,473
W-081	Truck, Panel 1 ton	94	99,346	120,892	21,546
W-082	Truck, Panel 1 ton	94	164,767	180,926	16,159
W-083	Truck, Carryall 1 ton	96	87,985	108,534	20,549
W-084	Truck, Carryall 1 ton	95	131,802	154,710	22,908
W-085*	Truck, Carryall 1 ton	95	110,792	128,338	17,546
W-087*	Truck, Carryall 1 ton	96	60,973	84,864	23,891
W-098	Truck, Carryall 1 ton	96	126,396	170,378	43,982
W-099	Truck, Carryall 1 ton	94	114,590	123,449	8,859
W-100*	Truck, Van 5 ton	96	28,735	34,503	5,768
W-101*	Truck, Van 5 ton	96	22,815	34,676	11,861
W-112*	Truck, Stake 5 ton	97	41,393	60,740	19,347
W-120*	Truck, M.S.D. ¾ ton	98	26,257	32,199	5,942
W-125	Truck, Tank Water	95	1,960	2,828	868
W-201*	Truck, Wrecker 5 ton	97	5,770	6,995	1,225
W-205*	Truck, Wrecker 2½ ton	95	13,471	18,579	5,108
W-210*	Bus, 45 Passenger	92	8,277	14,526	6,249
W-220*	Bus, 25 Passenger	97	69,072	92,161	23,089
W-223*	Truck, Tractor 6X4	95	2,638	3,413	775
W-250	Bus, 45 Passenger	94	22,181	27,620	5,439
W-270*	Bus, 45 Passenger	96	132,633	145,973	13,340

TABLE 5. Emergency Vehicles Converted to JP-8 at Camps Henry and Long

ID Number	Vehicle Type	Model Year	Km/Miles at Sampling	Number of Cylinders	Injection Type	MFR
T-77	Ambulance, F-350	92	11,484	8	Distributor	Ford
T-69	Ambulance	94	602	4	Distributor	Daewoo
T-450	Fire Truck	90	8,602	6	Unit Injector	Ameritex
T-451	Fire Truck	87	15,593	6	Unit Injector	Ameritex
T-452	Fire Truck	92	7,623	6	In-Line	Daewoo
T453	Fire Truck	89	7,006	6	Unit Injector	Ameritex
W-500	Ambulance, F-350	93	21,308	8	Distributor	Ford
W-501	Ambulance	94	13,167	4	Distributor	Hyundai
W-400	Fire Truck	87	124	6	Unit Injector	Ameritex
W-401	Fire Truck	87	14,189	6	Unit Injector	Ameritex
W-402	Fire Truck, Donga	87	6,480	6	In-Line	Daewoo

Figure 27. F-350 Ambulance Truck

Figure 28. 1-ton Ambulance Truck

Figure 29. Fire Truck

Figure 30. Fire Truck

Figure 31. Fire Truck

Figure 32. Fire Truck

Figure 33. Fire Truck

Figure 34. Fire Truck

VI. DISCUSSION AND RESULTS

A. Chemical Analysis of JP-8 and Diesel Fuel Samples

1. Discussion

Table 6 shows the test protocols used to analyze the JP-8 and diesel fuel samples obtained from NTV test vehicles and bulk storage tanks at Camps Henry and Long.

TABLE 6. Analyses Protocol

JP-8 Samples		Diesel Samples	
Laboratory Test	**Method**	**Laboratory Test**	**Method**
BOCLE, mm	D 5001	BOCLE, mm	D 5001
HFRR@ 60°C, micron	D 6079	HFRR@ 60°C, micron	D 6079
SWLT, g	D 6078	SWLT, g	D 6078
Sulfur, Mass%	D 4294	Sulfur, Mass%	D 4294
Flash Point, °C	D 93	Flash Point, °C	D 93
KVIS@ 40°C Cst	D 445	KVIS@ 40°C Cst	D 445
Particulates, MG/L	D 5452	Particulates, MG/L	D 5452
Static Dissipater Additive	D 2624		
FSII, Vol%	D 5006		

Several concerns were identified as potential problems; the laboratory tests shown in Table 6 were intended to address these concerns, but not to represent a complete listing of specification requirements. Lubricity of kerosene-based fuels used in diesel equipment has been a concern since the change-over from DF-2 to JP-8 was initiated.

The following ASTM laboratory tests are used to evaluate a fuel's lubricity potential: D5001, D6079 and D6078. Several other tests are mentioned because of their usefulness in evaluating other properties.

ASTM D5001 assesses the wear aspects of the boundary lubrication properties of aviation turbine fuels on rubbing steel surfaces. A non-rotating steel ball is mounted against a test cylinder, which generates a wear scar on the steel ball; the resulting measurement is used as a lubricity rating.

ASTM D6079 is a standard test used to evaluate diesel fuel lubricity by high-frequency reciprocating motion in a high-frequency reciprocating rig (HFRR).

ASTM D6078 is a standard method for evaluating the lubricity of diesel fuels by a scuffing load placed on the ball-on-cylinder lubricity evaluator. Basically, this procedure evaluates the load-carrying capacity of the fuel, which could be middle distillate fuels such as low-sulfur Nos. 1 and 2 diesel fuel.

ASTM D4294 is a standard test procedure to measure the sulfur content in fuel using energy dispersive X-ray fluorescence. This procedure covers the determination of sulfur in most hydrocarbon fluids, including range of concentration. The sulfur range that can be measured by this procedure is 0.0150 to 5.00 mass percent sulfur.

ASTM D445 determines the kinematic viscosity of the fuel at 40°C. Viscosity determination at 40°C is not a JP-8 specification requirement, however, it is useful when conducting engine testing. Typical viscosity values at 40°C vary approximately 1.2 to 1.3 cSt and are considered a factor in pump performance.

ASTM D5452 covers gravimetric determination by filtration of particulate contamination in the fuel. Although, the role of contamination is not fully understood, increased component wear and filter plugging are believed to be associated with particulate contamination, of course, depending upon the source of the contaminant.

ASTM D2624 covers the determination of the electrical conductivity of the fuel, with and without a static dissipater additive. Electrical conductivity is considered an important safety factor because fuels, when pumped, are known to build up an electrical charge that can act as an ignition source of the fuel vapor or even foam that has not collapsed.

ASTM D5006 determines the presence of a system icing inhibitor; however, it does not identify which inhibitor is present. Basically, this procedure is sued to measure the concentration of ethylene, glycol, monomethyl ether (EGME) or diethylene glycol monomethyl ether (DiEGME) in aviation fuels. The procedure is based on refractive index determination using a refractometer.

2. Results

a. Generalized Analysis Results

i. Camp Henry

Twenty-six JP-8 fuel samples were analyzed. The best (and only) comparison must be made with the reference fuel from the fueling point (FP). With some allowance for analytical variation, the following comments are made.

Diesel fuel contamination was found in at least nine of the 26 samples taken directly from the vehicles. Although the source of the contamination was discussed with motor pool personnel, no direct answers were provided. It was suggested that some drivers still like to use diesel fuel regardless of instructions. It is unfeasible that the diesel fuel was a carry over from the initiation of testing eight months previous.

When comparisons were made with the fueling point sample, the presence of diesel fuel found in 30% of the samples greatly biased any averages that could be made. When a closer analysis was conducted, it seems possible that even more vehicles were contaminated . For instance, vehicles T-96 and T-145 did not show signs of being contaminated based on certain properties such as viscosity; however, the sulfur level is 25% below the reference fuel. It is unclear where to place the cutoff point for viscosity for unadulterated fuel samples.

ii. Camp Long

Twenty-seven samples were taken at Camp Long, including one from the fueling point to use as a reference sample. Of the 26 samples taken from the vehicles, at least 11 were probably contaminated with diesel fuel. It is interesting to note that the Camp Long fuel sample had only 0.05% sulfur compared to 0.08% sulfur from Camp Henry. It is unclear how such a high percentage of vehicles appear to be contaminated with diesel fuel when the diesel fuel storage/dispensing point is at Camp Eagle Point, approximately 15 miles from the Camp Long motor pool.

While the viscosity at 40°C is not a specification property, it was used as a reference point for identifying fuel contamination, using approximately 1.2 cSt as the average value. If the 1.2 cSt is used as a reference point with 1.3 cSt as the cutoff point, as many as 15 of the 26 vehicle samples could have been contaminated with diesel fuel. It appears that the diesel fuel was a low-sulfur fuel.

Detailed analytical results of the chemical analyses of the used samples are presented in Appendix A.

b. Statistical Summary Results of Fuel Properties

i. Supply Point Fuel Analysis for DL-2 and JP-8

The fuel supplied to the Korean NTV test vehicles were evaluated from samples taken at the Camp Henry and Camp Long fuel supply points. Three diesel fuel samples were obtained; one from the supply point at Camp Henry, one from a diesel control vehicle at Camp Henry, and one from the control vehicle at Camp Long. The diesel fuels analyses are shown in Table 7, along with the ASTM D 975 specifications for comparison. The sample from the control vehicle looks like comingled fuel because the flash point and viscosity are larger than expected. A supply point JP-8 sample was obtained at each of Camp Henry and Camp Long. Their analyses are also shown in Table 7 along with the MIL-PRF-83133 specification requirements. The Camp Henry JP-8 meets all specification requirements. The Camp Long JP-8 is below the FSII minimum requirement, which may indicate the presence of water in the fuel supply system.

ii. Vehicle Fuel Analysis for JP-8

The summary statistics for the fuel samples obtained from the entire set of Korean NTV test vehicles (both locations) are shown in Table 8. The nature of the demonstration being JP-8 acceptance testing, it would be expected that the vehicle fuel sample properties would mimic the supply point JP-8 fuels. In Table 8, the mean is the arithmetic average of the results. The median is the middle value of the distribution, above and below which lie an equal number of values. The mode is the most frequently occurring, or repetitive, value in the range of data. The skewness statistic characterizes the degree of asymmetry of a distribution around its mean. Positive skewness indicates a distribution tending toward higher values, negative tending toward lower values. The kurtosis statistic characterizes the relative flatness of a distribution compared with the normal distribution. Positive kurtosis indicates a peaked distribution, negative a flat distribution. The frequency distribution of test results for the fuel properties measured are shown in Figures 35 through 43.

TABLE 7. Fuel Supply Point Fuel Analysis for DL-2 and JP-8

Korean NTV Supply Point and Control Vehicle Fuel Analysis								
Location		Supply and Control Vehicle DL-2			ASTM D975 Specification	Supply JP-8		MIL-DTL-83133 Specification
		Camp Henry Fuel Supply	Control Vehicle	Camp Long Control Vehicle		Camp Henry	Camp Long	
Test	Method	AL-25941-F	AL-25942-F	AL-25943-F		AL-25899-F	AL-25933-F	
BOCLE, mm	D 5001	0.55	0.53	0.54	NR	0.61	0.58	0.65 max*
HFRR @ 60°C, microns	D 6079	325	340	420	NR (450 max)†	600	765	NR (540/610 max) ††
SLWT, g	D 6078	3300	3000	3200	NR (3100 min) †	1900	1800	NR (2000-2800) †††
Sulfur, Mass%	D 4294	0.04	0.04	0.05	0.05 max	0.08	0.05	0.3 max
Flash Point, °C	D 93	51	48	52	52 min	45	47	38 min
KVIS @ 40°C cSt	D 445	2.49	1.42	2.54	1.9 – 4.1	1.19	1.21	NR
Particulates mg/L	D 5452	0.68	1.00	0.16	NR	0.25	0.16	1.0 max
Static Dissipater Additive, pS/m	D 2624					210	170	50-600
FSII, Vol%	D 5006					0.10	0.05	0.1-0.15

* Performance requirement for corrosion inhibitor additive specified in MIL-A-25017.
† Engine Manufacturers Association recommendation for lubricity of diesel fuels.
†† U.S. Army HFRR recommendation at 25°C/estimated at 60°C
††† U.S. Army recommendation, additive treatment required below 2000 grams, optional from 2000-2800 grams

TABLE 8. Summary Statistics for Vehicle Fuel Tank Samples

Korean Non-Tactical Vehicle Fuel Tank Samples

Summary Statistics	BOCLE, mm	HFRR @ 60°C, microns	SLWT, g	Sulfur Mass%	Flash Point, °C	KVIS 40°C, cSt	Particulate, mg/L	Static Dissipater Additive, pS/m	FSII, Vol%
	D 5001	D 6079	D 6078	D 4294	D 93	D 445	D 5452	D 2624	D 5006
minimum	0.53	310	1600	0.04	43	1.02	0.13	80	0.005
mean	0.57	641	2363	0.06	46	1.40	0.61	266	0.061
median	0.57	690	2100	0.06	46	1.27	0.40	240	0.060
mode	0.57	780	1950	0.05	45	1.23	0.41	430	0.096
maximum	0.59	810	3600	0.08	52	2.34	5.61	610	0.100
standard deviation	0.018	149	593	0.013	2.1	0.300	0.878	139	0.0275
skewness	-0.567	-0.786	0.729	0.191	0.495	1.509	4.592	0.561	-0.204
kurtosis	-0.392	-0.716	-0.835	-1.000	-0.534	1.572	23.080	-0.605	-1.127

The frequency distributions for the ASTM D 5001 Ball-On-Cylinder-Lubricity-Evaluator (BOCLE) tests for 51 Korean vehicle fuel tank samples are shown in Figure 35. All samples were below the 0.65-mm maximum for the corrosion inhibitor in JP-8. The mean, median, and mode are at the same value of 0.57-mm. The skewness statistic indicates that the samples are biased towards lower wear scars. The kurtosis statistic indicates the data distribution is flatter than normally distributed data. These biases indicate a contamination of the fuel by higher lubricity components. This result would be consistent with commingling of JP-8 and DL-2.

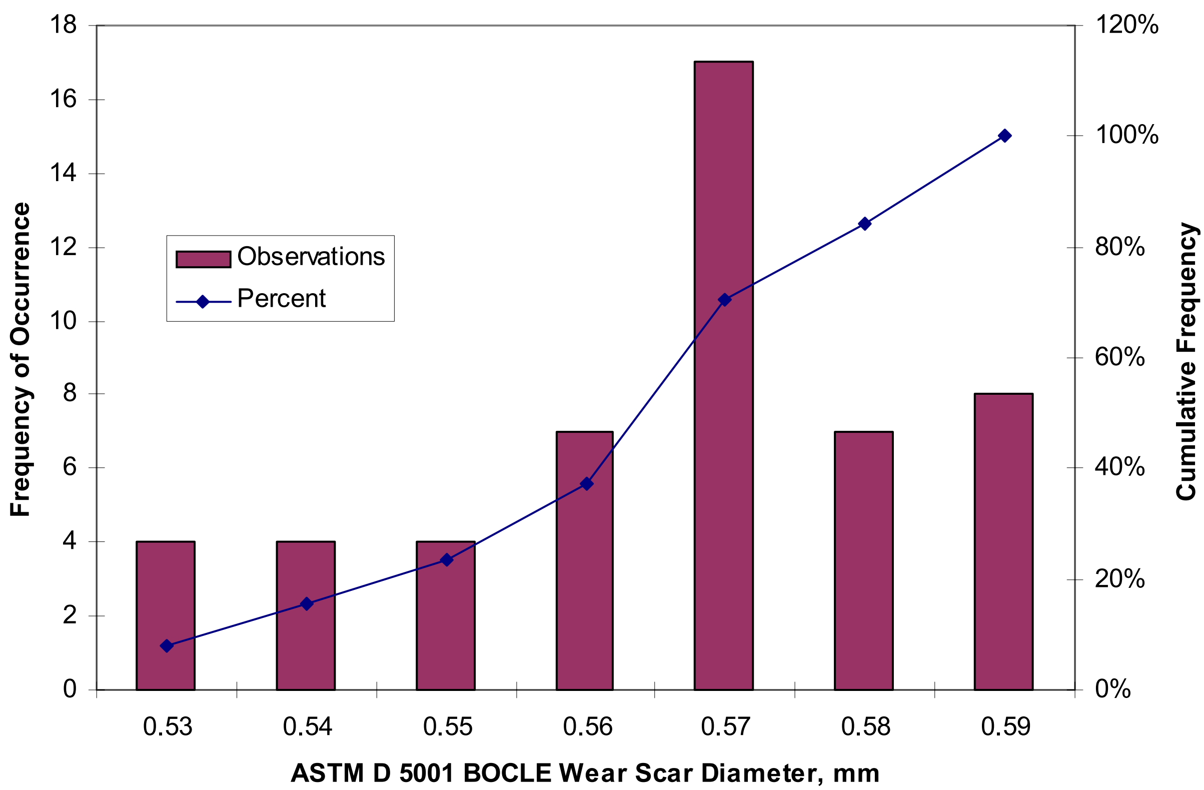

Figure 35. ASTM D5001 BOCLE Result Distribution for Korean NTV Fuel Samples

The frequency distributions for the ASTM D 6079 High-Frequency-Reciprocating-Rig (HFRR) results for 51 Korean vehicle fuel tank samples are shown in Figure 36. Fifty-five percent of the samples have wear scars greater than the U.S. Army recommendation for JP-8 lubricity with HFRR of 540-mm maximum at 25°C, approximately equivalent to 610-mm at 60°C. The mean value is 641-mm, the median value is 690-mm, whilst the mode value is 780-mm. The skewness statistic indicates the samples are biased towards lower wear scars. The kurtosis statistic indicates a flat distribution. These biases indicate contamination of the fuel by higher lubricity components. As with the BOCLE results, this result would be consistent with the commingling of JP-8 and DL-2.

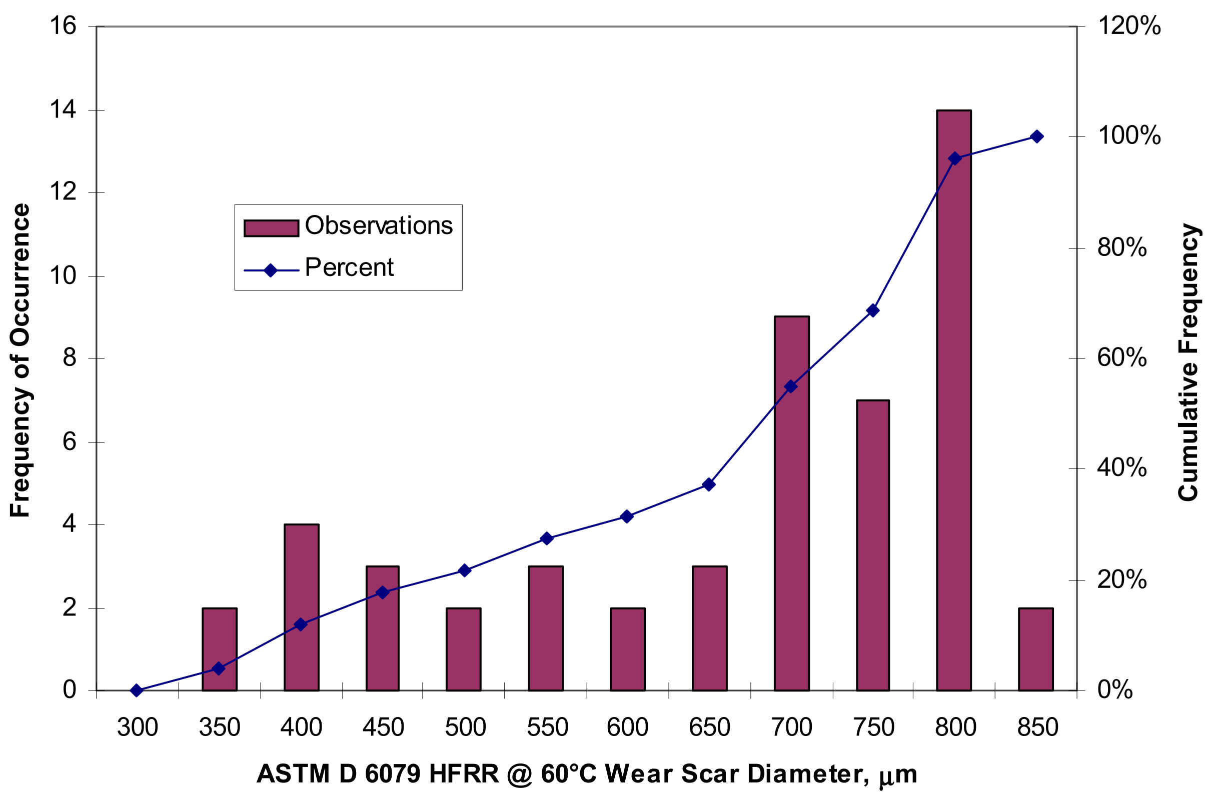

Figure 36. ASTM D6079 HFRR Result Distribution for Korean NTV Fuel Samples

The frequency distributions for the ASTM D 6078 Scuffing Load Wear Test (SLWT) results for 51 Korean vehicle fuel tank samples are shown in Figure 37. Sixty-four percent of the samples have scuffing loads lower than the U.S. Army 2800-gram recommendation for voluntary addition of lubricity improver to JP-8. Voluntary addition of additive is recommended for scuffing loads of 1500-to-2800-grams, and additive treatment required for scuffing loads below 1500-grams. The mean value is 2363-grams, the median value is 2100-grams, whilst the mode value is 1950-grams. The skewness statistic indicates the samples are biased towards higher scuffing loads. The kurtosis statistic indicates a flat distribution. As with the BOCLE and HFRR results, these biases indicate contamination of the fuel by higher lubricity components. These results are consistent with the commingling of JP-8 and DL-2.

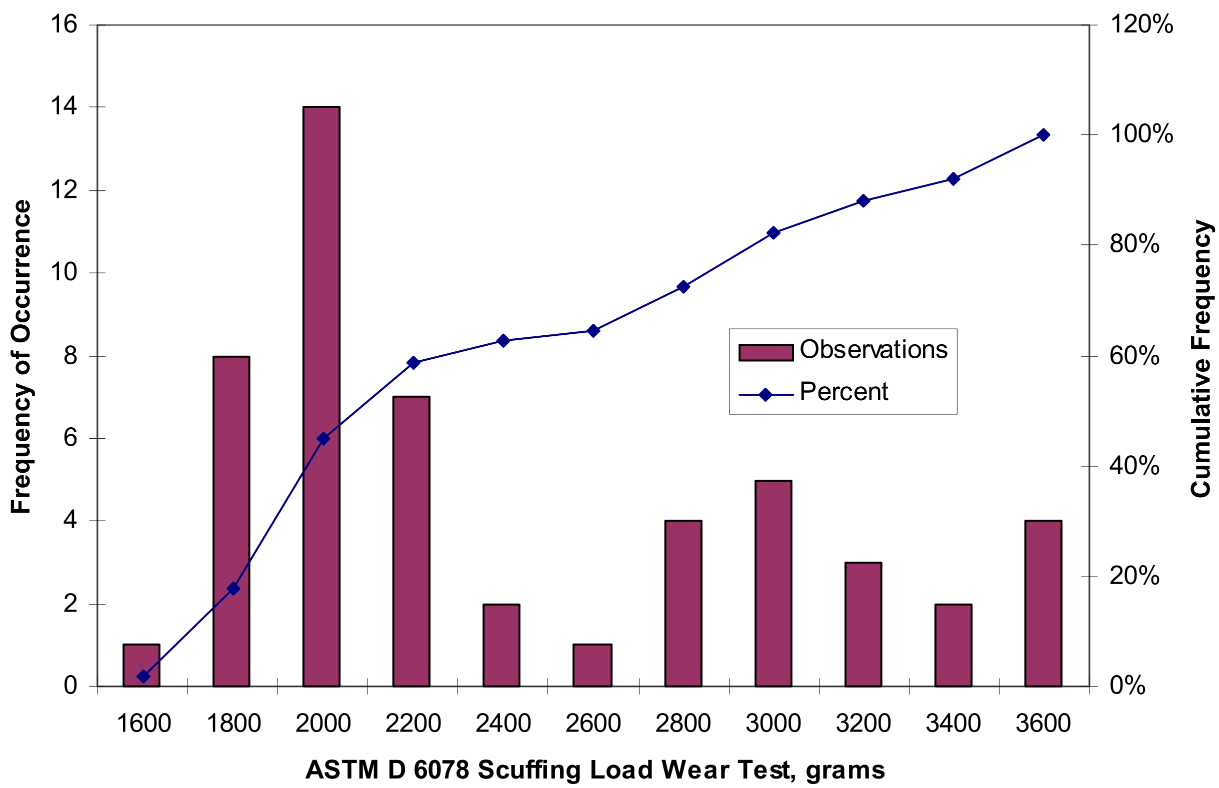

Figure 37. ASTM D6078 Scuffing Load Wear Test Result Distribution for Korean NTV Fuel Samples

The frequency distributions for the ASTM D 4294 mass percent sulfur for 51 Korean vehicle fuel tank samples are shown in Figure 38. All samples were below the 0.3% maximum sulfur specification for JP-8. Forty percent of the samples would qualify as low sulfur diesel fuel. The mean sulfur value was 0.06%, the median value 0.06%, and the mode was 0.05% sulfur. The skewness statistic indicates that the samples are biased towards values larger than the mean. The kurtosis statistic indicates the data distribution is flatter than normally distributed data.

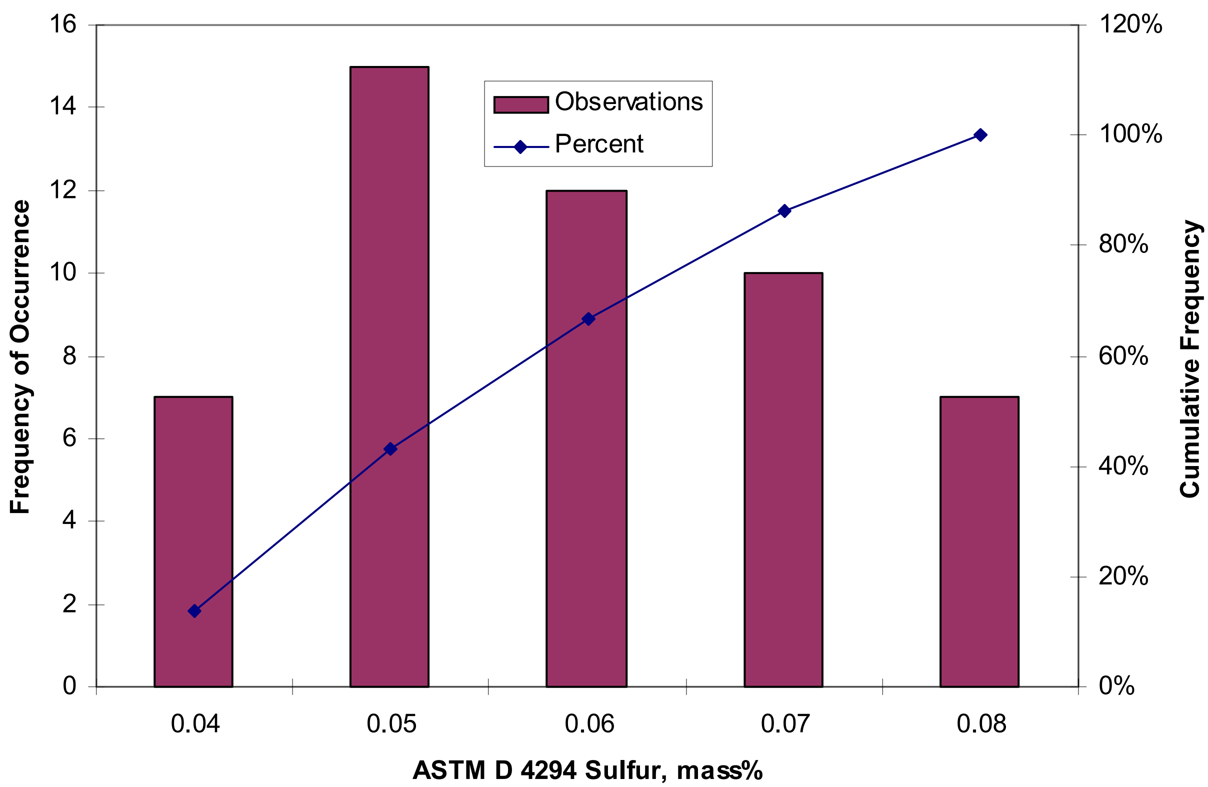

Figure 38. ASTM D4294 Sulfur Result Distribution for Korean NTV Fuel Samples

The frequency distributions for the ASTM D 93 flash point results for 51 Korean vehicle fuel tank samples are shown in Figure 39. All samples were above the 38°C flash point minimum for JP-8. The mean, median, and mode were within 1°C of being the same value. The skewness statistic indicates that the samples are biased towards flash points greater than the mean. The kurtosis statistic indicates the data distribution is flatter than normally distributed data. These biases would be consistent with commingling of JP-8 and DL-2.

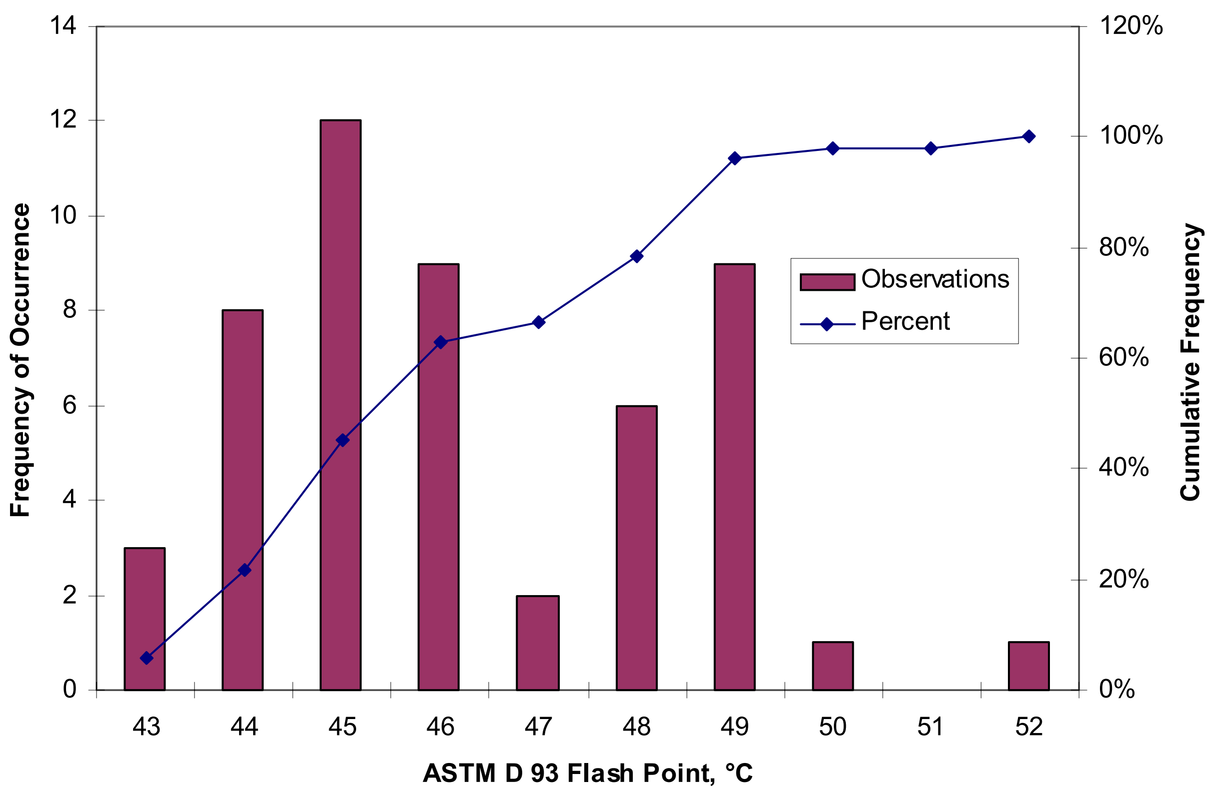

Figure 39. ASTM D93 Flash Point Result Distribution for Korean NTV Fuel Samples

The frequency distributions for the ASTM D 445 kinematic viscosity at 40°C for 51 Korean vehicle fuel tank samples are shown in Figure 40. The kinematic viscosity at 40°C is not a specification for JP-8, but is considered a property that effects fuel lubricity for rotary injection pumps. The mean viscosity is 1.40-cSt, the median value 1.27-cSt, whilst the mode value was 1.23-cSt. The high mean value suggests contamination with DF-2 in some of the vehicle fuel tanks. The skewness statistic indicates that the samples are biased towards viscosity greater than the mean. The kurtosis statistic indicates the data distribution is more peaked than normally distributed data.

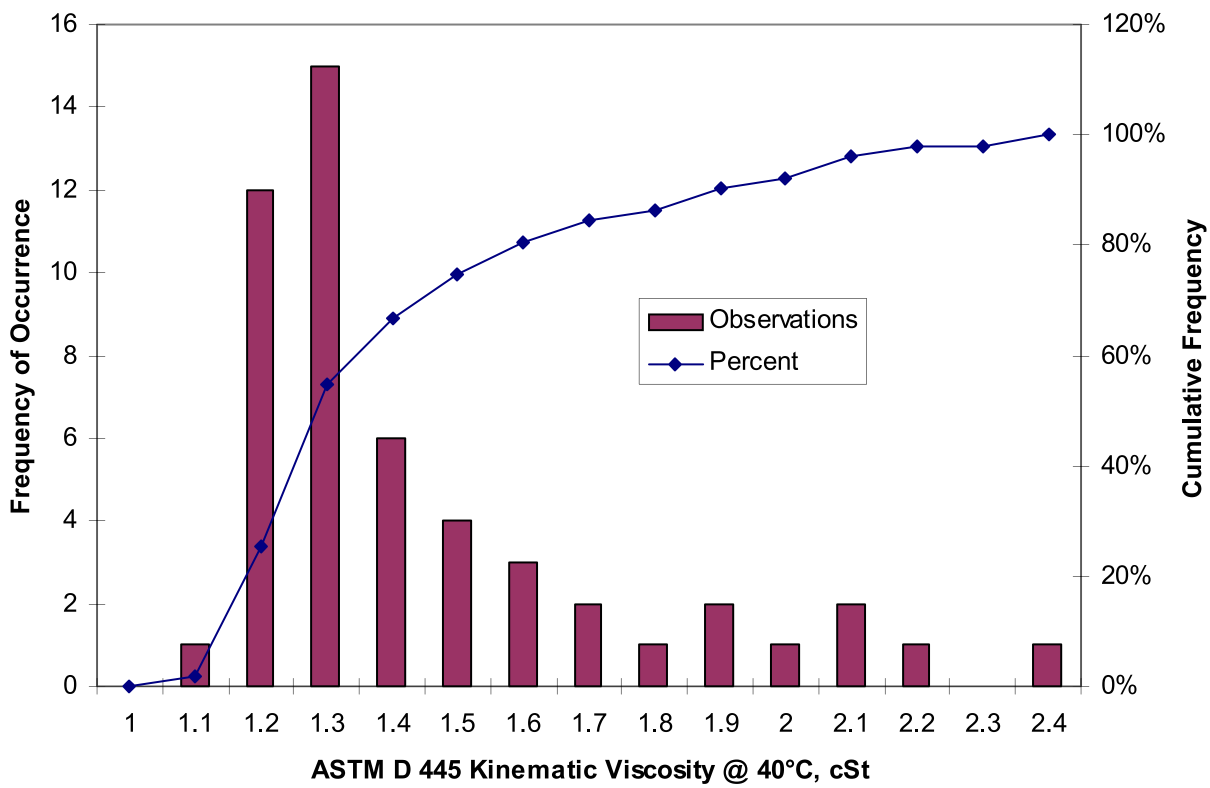

Figure 40. ASTM D445 Kinematic Viscosity Result Distribution for Korean NTV Fuel Samples

The frequency distributions for the ASTM D 5452 particulate reults for 51 Korean vehicle fuel tank samples are shown in Figure 41. Ninety percent of the samples were below the 1.0-mg/L maximum for particulate contamination in JP-8. The mean was 0.61-mg/L, the median value was 0.40-mg/L, and 0.41-mg/L was the mode value. The skewness statistic indicates that the data is biased towards contamination levels greater than the mean. This data set is effected by several samples that revealed large quantities of contaminants. The kurtosis statistic indicates the data distribution is peaked.

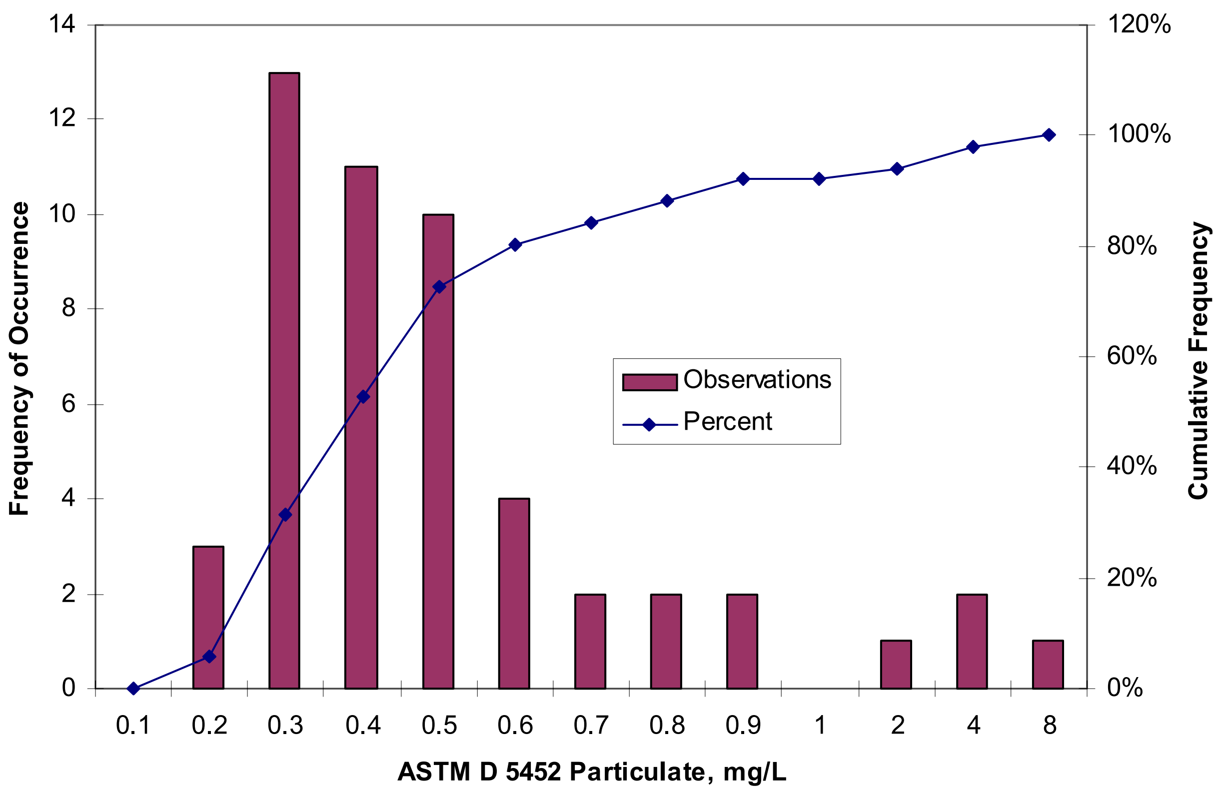

Figure 41. ASTM D5452 Particulate Result Distribution for Korean NTV Fuel Samples

The frequency distributions for the ASTM D 2624 static dissipater additive results for 51 Korean vehicle fuel tank samples are shown in Figure 42. Ninety-five percent of the samples were within the 50-600-pS/m-specification range for JP-8. The mean value was 266-pS/m, the median value was 240-pS/m, whilst the mode value was 430-pS/m. The skewness statistic indicates that the data is biased towards conductivity levels greater than the mean. The kurtosis statistic indicates the data distribution is flatter than normally distributed data.

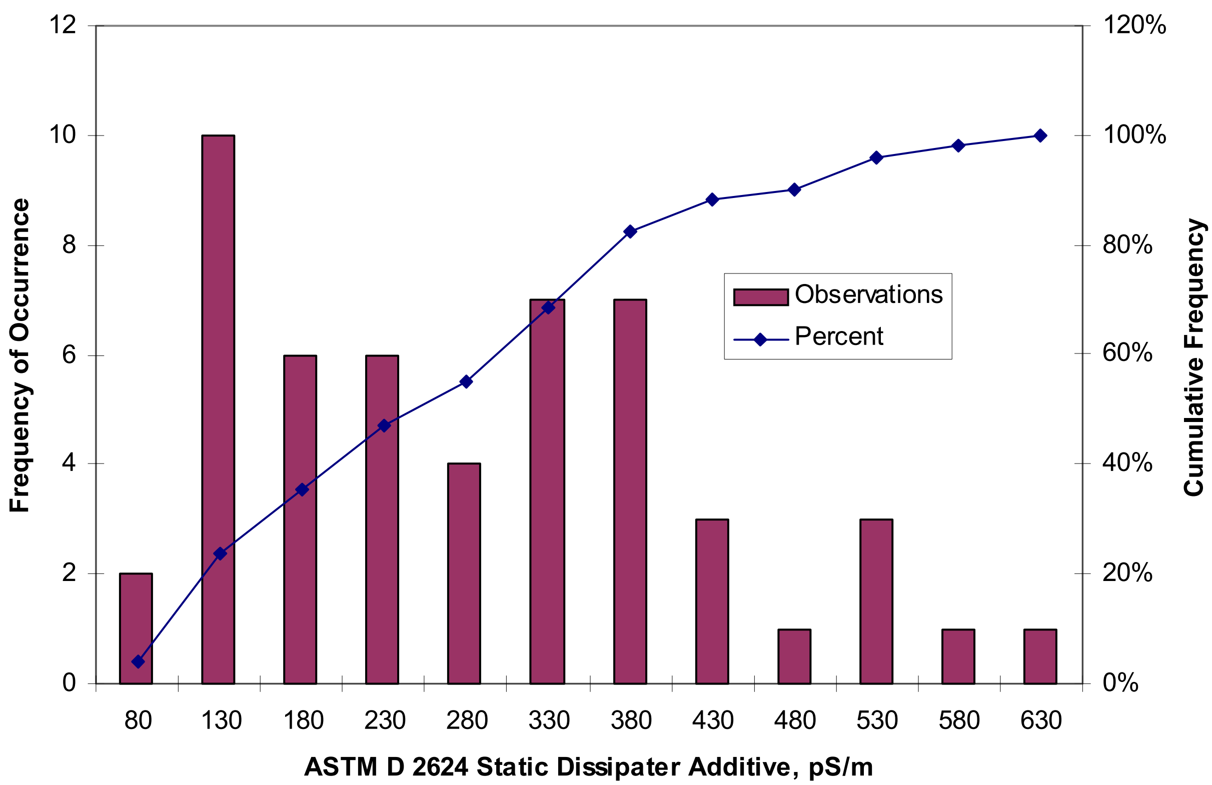

Figure 42. ASTM D2624 Static Dissipater Additive Result Distribution for Korean NTV Fuel Samples

The frequency distributions for the ASTM D 5006 Fuel System Icing Inhibitor (FSII) results for 51 Korean vehicle fuel tank samples are shown in Figure 43. Eighty percent of the vehicle fuel tank samples were below the 0.1-vol.% minimum for FSII in JP-8. The mean was 0.061%, the median value was 0.06%, and mode was 0.096% FSII volume. The skewness statistic indicates that the data are biased towards lower FSII volumes than the mean. The low FSII result could be due to the presence of water in the fuel tanks, or a reflection of the vehicles that use the Camp Long fuel supply that had low FSII volumes. The kurtosis statistic indicates the data distribution is flatter than normally distributed data.

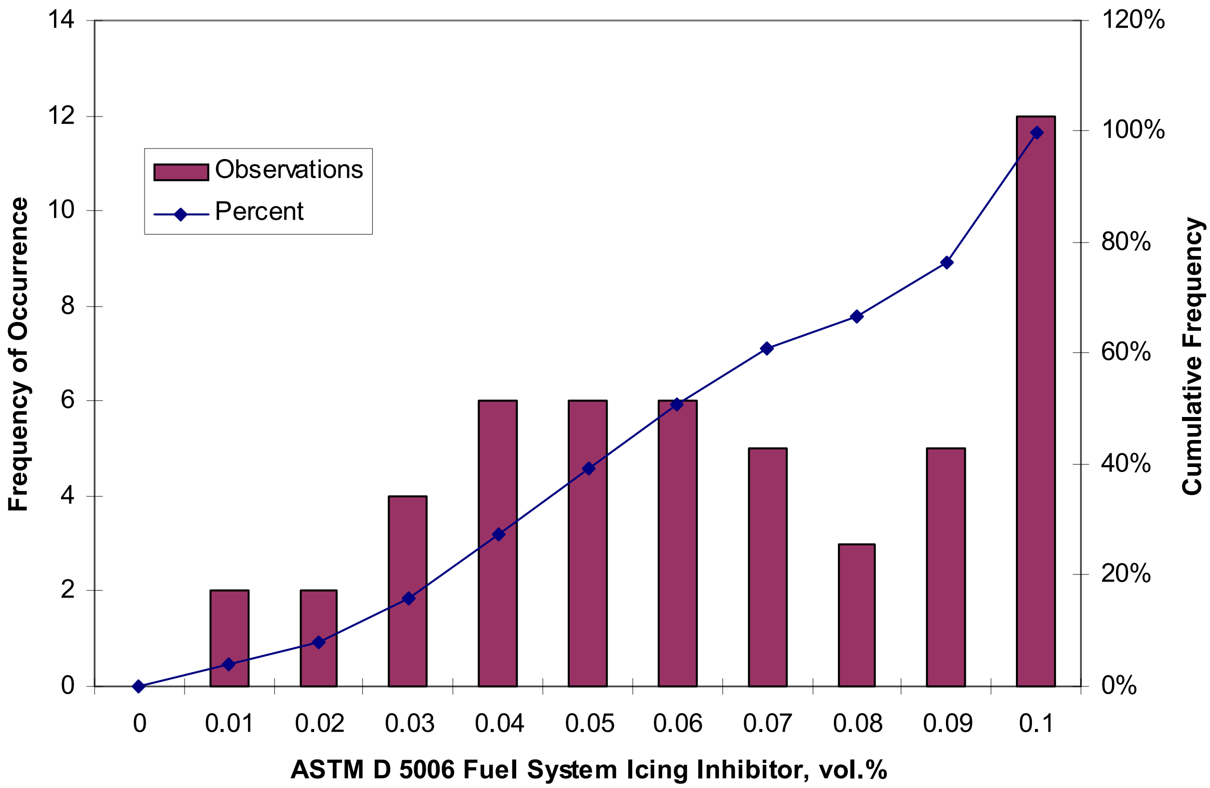

Figure 43. ASTM D5006 FSII Result Distribution for Korean NTV Fuel Samples

B. Injection Pump Investigation

1. Pump Descriptions

Table 9 summarizes the four injection pumps to be discussed, which were removed from vehicles operating normally at the Camp Henry motor pool, with the exception of pump SN662A0568. This pump was removed from a 45-passenger bus reporting severe power loss. The pumps represent a cross section of Korean-manufactured vehicles found in transportation motor pools throughout Korea and are shown in Figures 44 through 47.

TABLE 9. Vehicle Pump Identification

Pump MFR.	Doowon	Korea Diesel	Doowon	Doowon
Model	101603-9981	104740-7270	104745-9150	104745-4490
Serial Number	662A0568	267A5220	661A2256	B66614A2743
Type Pump	In - Line	Distributor	Distributor	Distributor
Vehicle MFR.	Daewoo	Ssanyong	KIA	Hyundai
Vehicle Type	45 PAX Bus	Truck Util ½ Ton	Truck Cargo 1 Ton	Truck Cargo 1Ton
Total Vehicle Km	50,662	50,020	40,003	41,148
Total JP-8 Km	16,341	9,006	6,885	10,415

a. Specific Details on Individual Pumps

Each pump was inspected for damage during shipment and other apparent anomalies prior to installation in the calibrated test stand. Following are specific details and observations on the four pumps tested.

i. Doowon In-Line Injection Pump - SN 662A0568

This Doowon 6-cylinder, in-line injection pump was removed from a 1996 Daewoo 45-passenger bus ID No. T-203 exhibiting noticeable power loss. The vehicle had 34,321 kilometers of operation on diesel when converted to JP-8, and it had operated 16,600 kilometers on JP-8 fuel when the pump was removed. The vehicle reportedly was experiencing severe power loss with JP-8. Motor pool maintenance personnel replaced fuel filters and cleaned the fuel lines as remedial actions to alleviate the power loss problem to no avail. When the pump was placed on the calibrating test stand, it would not produce

Figure 44. Doowon In-Line Fuel Injection Pump

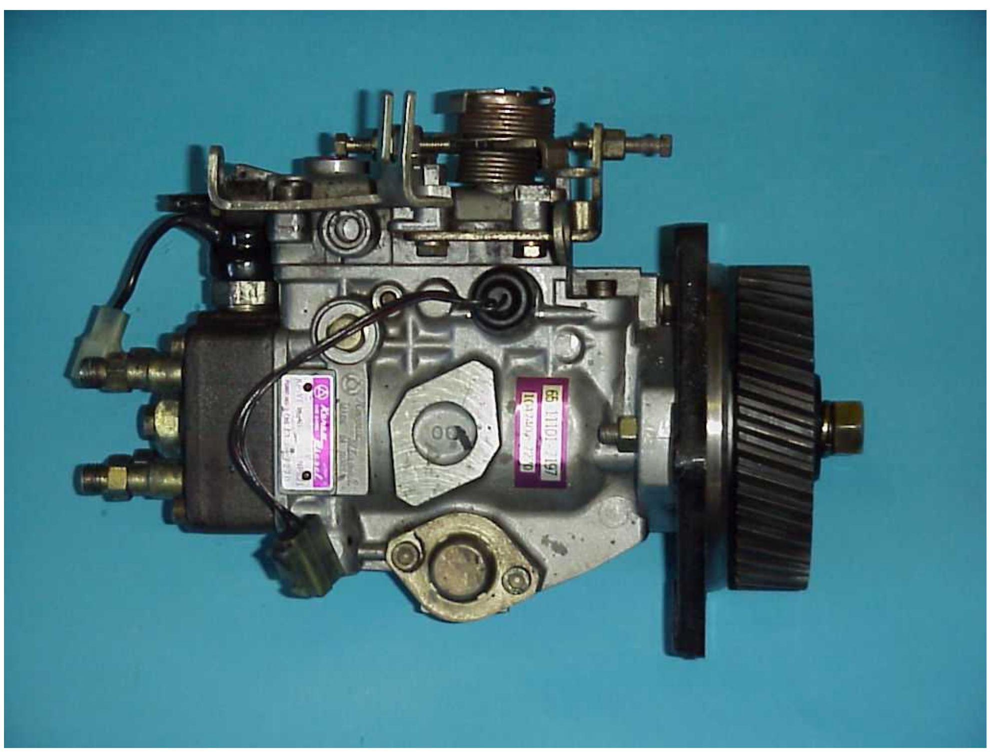

Figure 45. Korea Diesel Distributor Injection Pump

Figure 46. Doowon Distributor Injection Pump

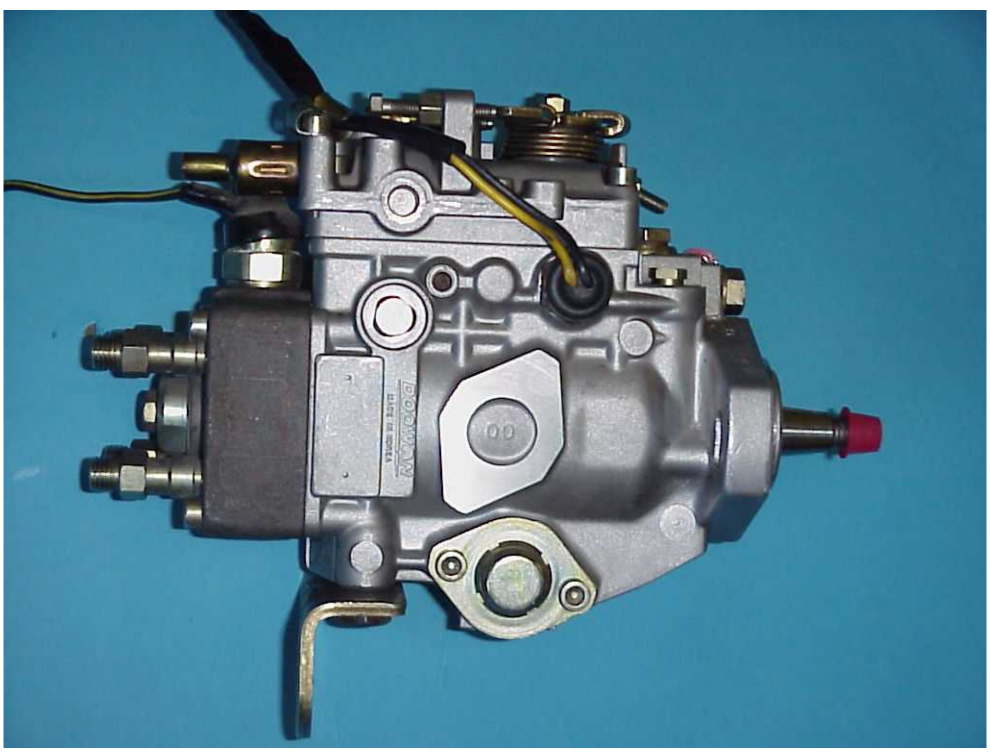

Figure 47. Doowon Distributor Injection Pump

adequate fuel flow rates. Upon inspection it was found that the primer pump assembly had been cross-threaded into the pump mounting orifice, introducing aluminum shavings into the pump inlet assembly and pump housing. The pump was removed, cleaned, flushed and again placed on the calibrating test stand where it produced proper flow rates at specified rpms. It was concluded that the aluminum shavings were blocking fuel flow orfices in the pump, thereby preventing proper fuel flow. This would account for the severe power loss that the vehicle was exhibiting.

ii. Korea Diesel Distributor Injection Pump - SN267A5220

This Korea Diesel 4-cylinder distributor injection pump was removed from a 1992 Ssangyong ½-ton utility truck ID No. T-152. The vehicle had operated for 41,014 kilometers on diesel when converted to JP-8 and had operated 9,006 kilometers on JP-8 fuel. The cover on the maximum flow set screw sealed by the manufacturer had been removed, and the adjusting screw had been screwed in to the maximum flow position. The position of the screw did not have any effect on the calibration results in the test stand. It is postulated that the vehicle's smoke exhaust increased with the setting change in the maximum flow set screw. However, no operational problems had been reported on this vehicle prior to the pump's removal.

iii. Doowon Distributor Injection Pump - SN661A2256

This Doowon 4-cylinder distributor injection pump was removed from a 1996 KIA 1-ton cargo truck ID No. T-36. The vehicle had 26,263 kilometers of diesel operation when converted to JP-8, and it had operated 6,885 kilometers on JP-8 fuel when removed from the vehicle. No anomalies were found and the calibration was performed with no incident.

iv. Doowon Distributor Injection Pump - SN66614A743

This Doowon 4-cylinder distributor injection pump was removed from a 1996 Hyundai 1-ton cargo truck ID No. T-42. The vehicle had 30,733 kilometers of operation on diesel when converted to JP-8, and it had operated 10,415 kilometers on JP-8 fuel when removed from the vehicle. Traces of oxidation were found on this pump indicating the possibility of water contamination at some point. The internal oxidation had no effect on the calibration results.

2. Methodology for Pump Evaluations

a. Injection Pump Calibration

Prior to calibrating the injection pumps, manufacturers' calibration specifications were obtained through the ASE Korea LTD., an engineering consulting firm in Seoul, Korea. The pumps were calibrated using a calibrated test stand. The purpose of the pump calibrations was to evaluate the pump's performance relative to how it was functioning in the vehicle prior to removal. During the procedure, the pumps were operated using ISO-4113 calibrating fluid, and performance was compared to the manufacturer's specifications at specific operating conditions and fuel temperatures.

Measurements were made at manufacturer-specified operating speeds and throttle positions, which are critical to engine operation. Principal parameters evaluated were injection timing, transfer pump pressures, and fuel delivery. The results of this analysis allow wear effects to be defined. It should be noted that these pumps had combined diesel and JP-8 usage; therefore degree of diesel and or JP-8 fuel wear could not be defined. No adjustments were made to any pumps to attain manufacturer's specifications.

b. Injection Pump Tear-Down Analyses

The pumps were disassembled at TFLRF following the completion of the evaluations on the calibrated test stand. Each pump was disassembled and rated for wear utilizing internally developed rating methodology. The SwRI pump disassembly and rating procedure was originally developed for the U.S. Army for use with Stanadyne equipment.(4) Each sliding contact within the pump is rated on a scale from 0 to 10, with 0 corresponding to no wear and 10 corresponding to severe wear and failure. The SwRI procedure has the advantage of including all wear contacts within the pump that are fuel lubricated, which allows this methodology to be applied to several pump designs like the Korean-manufactured pumps that were evaluated. The result from the SwRI evaluation procedure is the numerical average of all wear areas within the pumps. Table 10 enumerates the SwRI wear rating values.

TABLE 10. SwRI Wear Rating Values		
Value	**Wear Level**	**Wear Mechanism**
0	None	None
01 to 03	Good Result	Mild Adhesion / polishing
04 to 06	Border Line Result	Adhesive / Abrasive / oxidative
07 to 10	Failed Component	Scuffing / severe oxidative

3. Results

a. Calibrated Test Stand Evaluations Results

The pumps were tested in accordance with calibration sheets received from ASE Korea LTD. No history accompanied the pumps other than what was mentioned in Section IV, B1, a through d. There were no baseline numbers to compare readings obtained during the calibrated test stand evaluations; therefore the discussion in the present study will address the relative changes in pump performance observed, rather than differences of manufacturers' specifications. The differences observed during the calibration evaluations would not significantly effect engine operation. Flow rate readings were slightly higher with the ISO-4113 calibrating fluid used to calibrate the pumps due to higher viscosity in the KS-M2610 calibrating oil used in Korea. The largest differences in fuel delivery were noted during the full load mode in both high and low speeds. The difference was more pronounced in the Korea Diesel pump (SN 267A5220) due to the position of the flow set screw. Fuel delivery at specified pump pressure, timer and start rpm were for the most part unaffected. Fuel delivery at cranking speed (100 RPM) for all pumps was excellent. Reduced fuel delivery during low speed operation would produce hard starting, particularly at high-temperature conditions. Table 11 presents distributor injection pump calibration results of critical parameters.

Table 11. Distributor Inection Pump Calibration Results of Critical Parameters									
Manufacturer	**Korea Diesel**			**Doowon**			**Doowon**		
Model Number	**104710-7220**			**104745-9150**			**104745-4490**		
Serial Number	**267A5220**			**661A2256**			**6614A2743**		
Parameter	RPM	Spec. kg/cm²	Result	RPM	Spec. kg/cm²	Result	RPM	Spec. kg/cm²	Result
Pump Pressure	850 1300 1700 2300	3.9±0.3 5.0±0.2 5.9±0.3 7.5±0.5	3.9 5.0 5.8 7.2	500 1200 2000	1.9±0.3 3.9±0.3 5.9±0.3	2.3 4.3 5.9	600 1250 2100	3.2±0.3 4.8±0.3 6.8±0.3	3.0 4.8 6.9
Timer	850 100 1300 1700 2300	0.9±0.5 2.2±0.4 3.2±0.3 5.2±0.9 7.8±0.3	0.5 1.9 2.8 4.2 8.0	600 1200 2000	0.5±0.4 2.9±0.3 6.3±0.4	0.5 2.9 6.0	600 750 1250 1750 2100	1.4±0.4 1.8±0.4 3.6±0.4 5.2±0.4 6.9±0.4	1.0 1.8 3.6 5.0 6.7
Start	100	55 + 45	110.0	100	70-90	82.0	100	55-90	88.0

b. Injection Pump Wear Rating Results

Following the calibrated test stand evaluations, the pumps were disassembled and inspected at TFLRF. Photographs of selected components are provided in Appendix B. Individual inspected pump components and results of the wear inspections can be seen in Tables 12 and 13, respectively. Wear averages are plotted in Figure 48.

TABLE 12. Wear Rating Results for In-Line Injection Pump SN662A0568							
Feed Pump							
Piston to Cylinder	7						
Piston to Sliding Tappet	5						
		Cyl. 1	**Cyl. 2**	**Cyl. 3**	**Cyl. 4**	**Cyl. 5**	**Cyl. 6**
Plunger		5	6	6	6	5	5
Delivery Valve		6	3	6	5	6	6
Totals	12	11	9	12	11	11	11
Average						5.5	

TABLE 13. Wear Rating Results for Distributor Injection Pumps			
Pump Manufacturer	**Korea Diesel**	**Doowon**	**Doowon**
Model Number	104740-7220	104745-9150	104745-4490
Serial Number	267A5220	661A2256	66614A2743
Component			
Cam Plate			
Cam Path	1	2	4
Cam Plate Center	10	4	4
Cam Plate Claws	4	4	4
Rollers	2	6	8
Roller Bolts			
Contact to Roller	2	2	7
Contact to Roller Ring	2	2	3
Roller Bushing	4	3	4
Governor			
Flyweights	5	2	2
Butting Ring	5	2	1
Supply Pump			
Blades	4	4	4
Raceway	3	3	4
AVERAGE	**3.8**	**3.1**	**4.1**

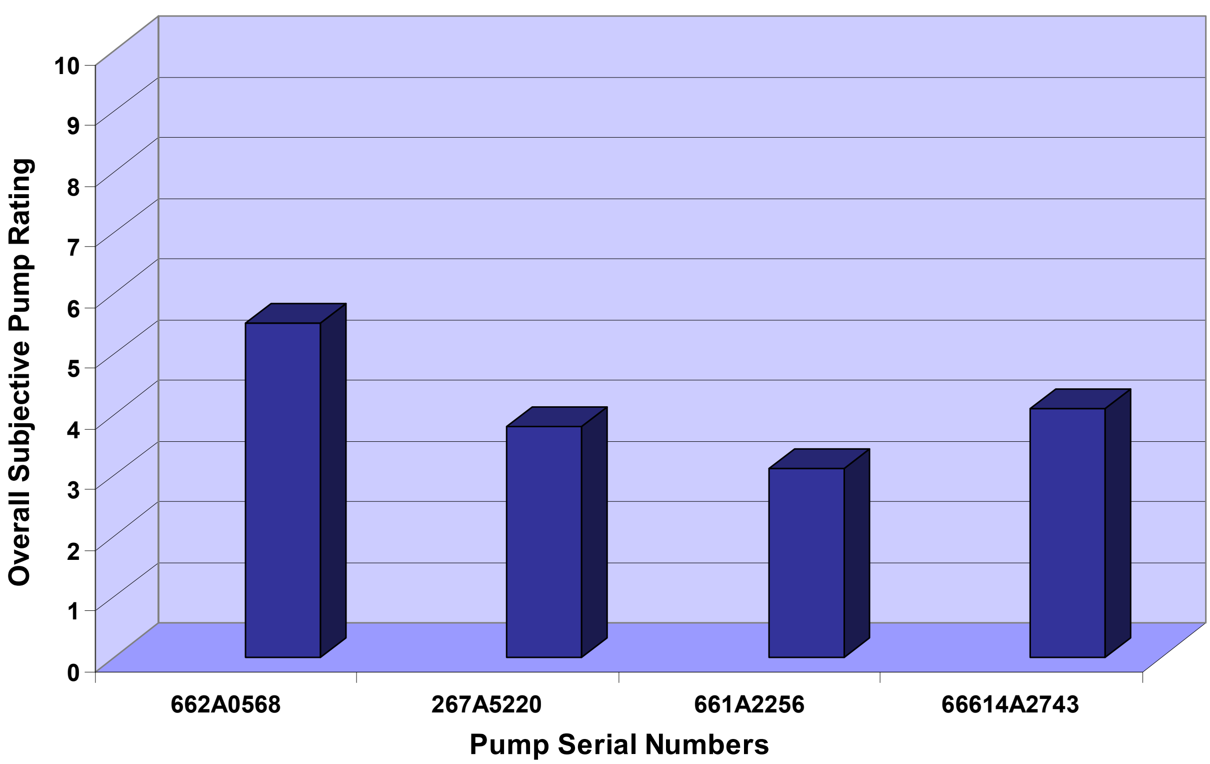

Figure 48. Pump Wear Rate Averages - TFLRF Procedure

Higher than normal wear expressed with a rating of six or higher was observed in several components in all the pumps; however, none would effect the pumps' performance. Some of the wear seen in the piston to cylinder, plunger and delivery valve of the in-line pump (Table 12, Figure 49) may have been caused by the metal debris found in the fuel inlet assembly and pump housing assembly prior to calibration evaluations. The severe wear observed in the cam plate center (Table 13, Figure 50) of the Korea Diesel pump (SN 267A5220) was probably caused by the additional pressure caused by the tampering of the fuel set screw. Similarly, the wear on the rollers and contact to rollers of the Doowon pump (SN 6614A2743) shown in Table 10 and Figures 51a and 51b, was probably precipitated by corrosion caused from water contamination as evidenced in the photographs taken at tear down. Photographs of rated components are shown in Appendix B.

The purpose of the wear evaluations was to determine if severe wear had occurred in the pumps from the use of JP-8 fuel. Since all of the pumps were exposed to diesel and JP-8 fuel, determining the degree of wear caused by diesel and the degree of wear caused by JP-8 would be speculative at best. However, it can be stated that the higher-than-normal wear observed in the pumps was the result of conditions other than diesel or JP-8 fuel.

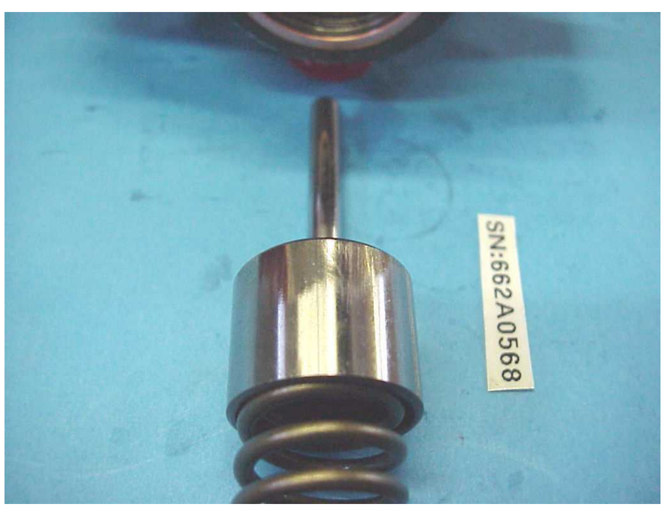

Figure 49. Piston to Cylinder

Figure 50. Cam Plate Center

Figure 51a. Rollers - Contact to Rollers

Figure 51b. Rollers, Bushing and Pin

VII. CONCLUSIONS

1. One hundred and two (102) 1987 to 1997 model year non-tactical vehicles ranging in size from ½ ton to 15 tons and encompassing most models of the major Korean automobile manufacturers participated in a year-long JP-8 conversion test without injection pump failures.

2. Based on data collected during the two visits to the units and from two cumulative usage reports submitted by the 19th TAACOM Transportation Officer, it was estimated that the vehicles at Camps Henry and Long accumulated approximately 1,365,512 kilometers and consumed 84,291 gallons of JP-8 fuel from 01 December 1998 to 30 November 1999.

3. Average vehicle usage was 13,387 kilometers. The highest kilometer accumulation was 43,992 km while the lowest was 379 km.

4. Laboratory fuel sample analysis confirmed that the JP-8 fuel used for the conversion test was in compliance with specification MIL-DTL-83133E, Turbine Fuels, Aviation, Kerosene Types.

5. Laboratory fuel sample analysis confirmed that approximately thirty-eight percent of the vehicle fuel samples obtained, were commingled with diesel fuel. Also, fifty-five percent of the samples have wear scars greater than the U.S. Army recommendation for JP-8 lubricity with HFRR of 540-mm maximum at 25°C, approximately equivalent to 610-mm at 60°C. Sixty-four percent of the samples have scuffing loads lower than the U.S. Army 2800-gram recommendation for voluntary addition of lubricity improver to JP-8. Voluntary addition of additive is recommended for scuffing loads of 1500-to-2800-grams, and additive treatment required for scuffing loads below 1500-grams. (3)

6. Calibration evaluations confirmed that all of the injection pumps conformed to critical fuel delivery and pump pressures specified in the manufacturers' calibration specification sheets.

7. Pump wear evaluations confirmed that higher than normal wear was noted on some components in all of the pumps; however, it did not affect the pumps' ability to perform satisfactorily.

8. Diesel fuel accounted for approximately 80 % of the pumps' usage upon removal from the vehicles; therefore it was not possible to access wear to either JP-8 or diesel fuel. It was found, however, that condition other than diesel or JP-8 fuel more than likely contributed to the wear found during the evaluations.

9. Based on the observations and evaluations of the 12 month demonstration program on the use of JP-8 fuel, it can be concluded that Korean manufactured non-tactical vehicles, to include emergency designated vehicles, can operate satisfactorily while using MIL-DTL-83133E, Aviation Turbine JP-8 fuel.

VIII. RECOMMENDATIONS

1. It is recommended that all the non-tactical fleet be converted to JP-8 fuel and maintenance personnel continue to monitor the fleet objectively until such time that it can be concluded that the lower viscosity and lubricity of JP-8 fuel is compatible with fuel wetted components in Korean manufactured vehicles.

2. It is further recommended that if in the process of using JP-8 fuel it is determined that injection pumps are showing accelerated wear, the JP-8 fuel be additive treated using the MIL-PRF-25017 Corrosion Inhibitor/Lubricity Enhancer at a treatment level of 250 ppm. This treatment level is ten times the normal level for this additive, and water separation characteristics of the fuel may be impacted.

3. It is also recommended that records of fuel wetted component replacements be maintained for proper documentation.

IX. REFERENCES

1. DOD Fuel Standardization Directive 4140.25, 21 April 1999.

2. MIL-DTL-83133E, Turbine Fuels, Aviation, Kerosene Types, 1 April 1999.

3. JP-8, The Single Fuel Forward Information Compendium January 1997.

4. Lacey, P.I. "Wear Mechanism Evaluation and Measurement in Fuel Lubricated Components," Interim Report 286, Belvoir Fuels and Lubricants Research Facility, SwRI, Texas. ADA284870, September 1994.

APPENDIX A
Detailed Chemical Analyses

CAMP HENRYJP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		T-404	T-55	T-51	T-203	T-416
SAMPLE ID		AL25888F	AL25889F	AL25890F	AL25891F	AL25892F
LABORATORY TEST	METHOD					
BOCLE,mm	D 5001	0.58	0.58	0.55	0.58	0.59
HFRR @ 60° C, micron	D 6079	680	670	395	780	790
SWLT, g	D 6078	1900	1800	3600	1700	1600
SULFUR, MASS %	D 4294	0.08	0.08	0.04	0.06	0.07
FLASH POINT,° C	D 93	44	44	50	45	4 4
KVIS @ 40° C Cst	D 445	1.17	1.17	2.34	1.22	1.17
PARTICULATES, MG/L	D 5452	0.42	0.41	0.48	0.58	0.39
STATIC DISSIPATER	D 2624	240	250	80	460	100
FSSII, VOL %	D 5006	0.09	0.10	0.01	0.09	0.10

CAMP HENRYJP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		T-409	T-239	TMP89	T-166	T-42
SAMPLE ID		AL25893F	AL25894F	AL25995F	AL25896F	AL25897F
LABORATORY TEST	METHOD					
BOCLE,mm	D 5001	0.53	0.59	0.58	0.57	0.53
HFRR @ 60° C, micron	D 6079	420	785	770	660	340
SWLT, g	D 6078	3250	1700	1750	3050	3550
SULFUR, MASS %	D 4294	0.06	0.07	0.06	0.04	0.06
FLASH POINT,° C	D 93	46	45	45	48	4 8
KVIS @ 40° C Cst	D 445	1.58	1.20	1.21	1.58	1.83
PARTICULATES, MG/L	D 5452	0.32	0.72	0.62	0.85	0.58
STATIC DISSIPATER	D 2624	190	550	430	610	150
FSSII, VOL %	D 5006	0.06	0.10	0.10	0.06	0.04

CAMP HENRYJP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		T-182	FP*	T-96	T-145	T-235
SAMPLE ID		AL25898F	AL25899F	AL25900F	AL25901F	AL25902F
LABORATORY TEST	METHOD					
BOCLE,mm	D 5001	0.57	0.61	0.57	0.59	0.59
HFRR @ 60° C, micron	D 6079	805	600	665	780	780
SWLT, g	D 6078	1950	1900	1950	1950	1950
SULFUR, MASS %	D 4294	0.07	0.08	0.06	0.06	0.07
FLASH POINT,° C	D 93	45	45	43	46	4 4
KVIS @ 40° C Cst	D 445	1.18	1.19	1.27	1.23	1.19
PARTICULATES, MG/L	D 5452	0.34	0.25	0.31	0.41	0.53
STATIC DISSIPATER	D 2624	160	210	170	320	350
FSSII, VOL %	D 5006	0.09	0.10	0.08	0.06	0.10

CAMP HENRYJP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		T-206	T-403	T-152	T-47	T-54
SAMPLE ID		AL25903F	AL25904F	AL25905F	AL25906F	AL25907F
LABORATORY TEST	METHOD					
BOCLE,mm	D 5001	0.59	0.54	0.56	0.59	0.59
HFRR @ 60° C, micron	D 6079	740	385	705	775	810
SWLT, g	D 6078	1800	3400	2250	1850	2000
SULFUR, MASS %	D 4294	0.07	0.05	0.07	0.06	0.08
FLASH POINT,° C	D 93	44	49	45	45	4 4
KVIS @ 40° C Cst	D 445	1.18	2.17	1.88	1.20	1.78
PARTICULATES, MG/L	D 5452	0.35	0.13	0.54	0.40	0.26
STATIC DISSIPATER	D 2624	370	120	200	120	110
FSSII, VOL %	D 5006	0.10	0.01	0.04	0.06	0.09

CAMP HENRYJP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		T-413	T-79	T-38	T-125	T-232
SAMPLE ID		AL25908F	AL25909F	AL25910F	AL25911F	AL25912F
LABORATORY TEST	METHOD					
BOCLE,mm	D 5001	0.59	0.57	0.55	0.53	0.55
HFRR @ 60° C, micron	D 6079	800	770	770	310	600
SWLT, g	D 6078	1950	1950	1950	3200	1800
SULFUR, MASS %	D 4294	0.08	0.07	0.07	0.04	0.08
FLASH POINT,° C	D 93	44	43	44	48	4 3
KVIS @ 40° C Cst	D 445	1.16	1.67	1.18	2..05	1.14
PARTICULATES, MG/L	D 5452	0.19	0.40	0.61	0.88	0.44
STATIC DISSIPATER	D 2624	100	140	80	150	90
FSSII, VOL %	D 5006	0.09	0.10	0.09	0.03	0.09

CAMP HENRYJP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		T-413
SAMPLE ID		AL25913F
LABORATORY TEST	METHOD	
BOCLE,mm	D 5001	0.54
HFRR @ 60° C, micron	D 6079	795
SWLT, g	D 6078	1800
SULFUR, MASS %	D 4294	0.08
FLASH POINT,° C	D 93	45
KVIS @ 40° C Cst	D 445	1.20
PARTICULATES, MG/L	D 5452	0.41
STATIC DISSIPATER	D 2624	130
FSSII, VOL %	D 5006	0.10

CAMP LONG JP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		024	085	120	036	100
SAMPLE ID		AL25914F	AL25915F	AL25916F	AL25917F	AL25918F
LABORATORY TEST	METHOD					
BOCLE,mm	D 5001	0.54	0.57	0.57	0.57	0.57
HFRR @ 60° C, micron	D 6079	690	680	705	770	705
SWLT, g	D 6078	2750	2700	1900	2150	2150
SULFUR, MASS %	D 4294	0.06	0.06	0.07	0.05	0.05
FLASH POINT,° C	D 93	45	48	45	45	46
KVIS @ 40° C Cst	D 445	1.30	1.36	1.22	1.23	1.29
PARTICULATES, MG/L	D 5452	0.19	0.25	0.35	0.25	0.29
STATIC DISSIPATER	D 2624	290	310	130	120	500
FSSII, VOL %	D 5006	0.05	0.05	0.07	0.05	0.06

CAMP LONG JP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		017	034	270	210	201
SAMPLE ID		AL25919F	AL25920F	AL25921F	AL25922F	AL25923F
LABORATORY TEST	METHOD					
BOCLE,mm	D 5001	0.56	0.56	0.57	0.57	0.57
HFRR @ 60° C, micron	D 6079	500	505	460	780	695
SWLT, g	D 6078	2900	2750	2500	2150	2900
SULFUR, MASS %	D 4294	0.05	0.05	0.06	0.05	0.04
FLASH POINT,° C	D 93	49	49	46	45	46
KVIS @ 40° C Cst	D 445	1.42	1.02	1.23	1.23	1.32
PARTICULATES, MG/L	D 5452	0.36	0.28	1.10	0.26	0.48
STATIC DISSIPATER	D 2624	380	380	370	250	240
FSSII, VOL %	D 5006	0.02	0.02	0.08	0.06	0.08

CAMP LONG JP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		042	052	223	113	087
SAMPLE ID		AL25924F	AL25925F	AL25926F	AL25927F	AL25928F
LABORATORY TEST	METHOD					
BOCLE,mm	D 5001	0.56	0.59	0.58	0.57	0.58
HFRR @ 60° C, micron	D 6079	430	620	440	615	610
SWLT, g	D 6078	2550	1800	3050	2700	1850
SULFUR, MASS %	D 4294	0.05	0.06	0.08	0.05	0.04
FLASH POINT,° C	D 93	49	46	46	48	45
KVIS @ 40° C Cst	D 445	1.44	1.26	1.52	1.39	1.21
PARTICULATES, MG/L	D 5452	0.27	0.77	3.43	0.48	0.23
STATIC DISSIPATER	D 2624	330	100	290	430	160
FSSII, VOL %	D 5006	0.03	0.06	0.07	0.06	0.08

CAMP LONG JP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		018	043	093	150	FP*
SAMPLE ID		AL25929F	AL25930F	AL25931F	AL25932F	AL25933F
LABORATORY TEST	METHOD					
BOCLE,mm	D 5001	0.57	0.58	0.57	0.54	0.58
HFRR @ 60° C, micron	D 6079	675	730	750	370	785
SWLT, g	D 6078	2000	2200	2000	3500	1800
SULFUR, MASS %	D 4294	0.05	0.05	0.07	0.04	0.05
FLASH POINT,° C	D 93	49	47	46	52	47
KVIS @ 40° C Cst	D 445	1.38	1.27	1.24	1.03	1.21
PARTICULATES, MG/L	D 5452	0.25	0.25	0.31	5.61	0.16
STATIC DISSIPATER	D 2624	330	220	210	290	170
FSSII, VOL %	D 5006	0.03	0.04	0.06	0.03	0.05

CAMP LONG JP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		220	046	045	101	019
SAMPLE ID		AL25934F	AL25935F	AL25936F	AL25937F	AL25938F
LABORATORY TEST	METHOD					
BOCLE,mm	D 5001	0.57	0.57	0.57	0.56	0.56
HFRR @ 60° C, micron	D 6079	750	555	755	515	700
SWLT, g	D 6078	2050	2900	2000	3000	2350
SULFUR, MASS %	D 4294	0.05	0.05	0.06	0.05	0.05
FLASH POINT,° C	D 93	47	49	46	49	48
KVIS @ 40° C Cst	D 445	1.61	1.41	1.22	1.41	1.34
PARTICULATES, MG/L	D 5452	0.47	0.36	0.26	0.29	0.29
STATIC DISSIPATER	D 2624	490	370	130	510	340
FSSII, VOL %	D 5006	0.04	0.03	0.06	0.03	0.04

CAMP LONG JP-8 FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		015	205
SAMPLE ID		AL25939F	AL25940F
LABORATORY TEST	METHOD		
BOCLE,mm	D 5001	0.53	0.55
HFRR @ 60° C, micron	D 6079	375	510
SWLT, g	D 6078	3450	2900
SULFUR, MASS %	D 4294	0.04	0.05
FLASH POINT,° C	D 93	49	49
KVIS @ 40° C Cst	D 445	1.95	1.38
PARTICULATES, MG/L	D 5452	2.03	0.41
STATIC DISSIPATER	D 2624	200	430
FSSII, VOL %	D 5006	0.03	0.05

KOREAN NTV DIESEL FUEL ANALYSIS

FUEL SOURCE / VEHICLE ID		DL-2	T-83	040
SAMPLE ID		AL25941F	AL25942F	AL25943F
LABORATORY TEST	METHOD			
BOCLE,mm	D 5001	0.55	0.53	0.54
HFRR @ 60° C, micron	D 6079	325	340	420
SWLT, g	D 6078	3300	3000	3200
SULFUR, MASS %	D 4294	0.04	0.04	0.05
FLASH POINT,° C	D 93	51	48	52
KVIS @ 40° C Cst	D 445	2.49	1.42	2.54
PARTICULATES, MG/L	D 5452	0.68	1.00	0.16

APPENDIX B
Photographs of Rated Components

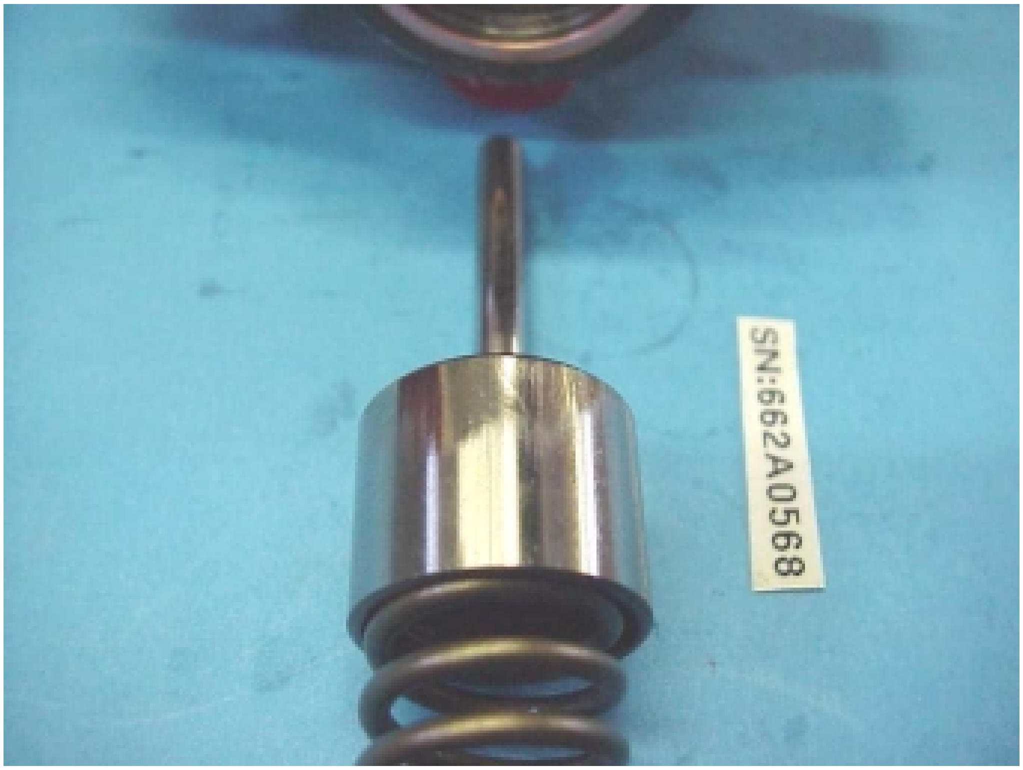

Figure B-1A. Piston to Cylinder

Figure B-1B. Piston and Sliding Poppet

Figure B-1C. Plunger

Figure B-1B. Delivery Valve

Figure B-2A. Cam Plate Path

Figure B-2B. Cam Plate Path

Figure B-2C. Cam Plate Path

Figure B-3A. Cam Plate Center

Figure B-3B. Cam Plate Center

Figure B-3C. Cam Plate Center

Figure B-4A. Cam Plate Claws

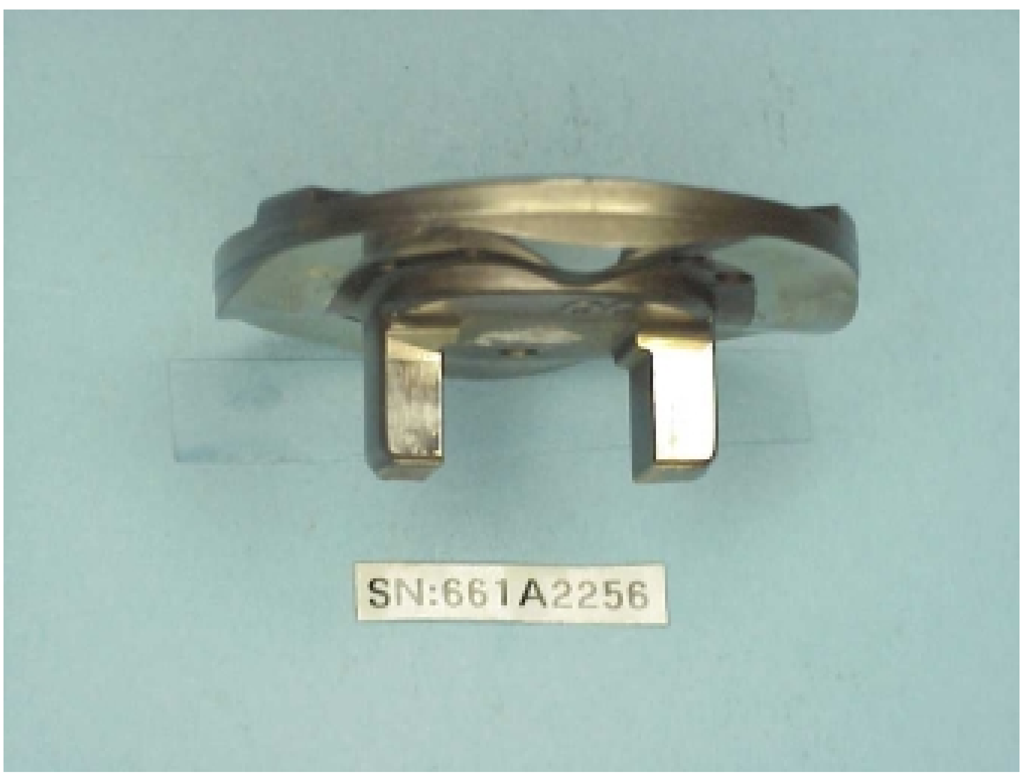

Figure B-4B. Cam Plate Claws

Figure B-4C. Cam Plate Claws

Figure B-5A. Cam Rollers and Holder

Figure B-5B. Cam Plate Rollers and Holder

Figure B-5C. Cam Plate Rollers and Holder

Figure B-6A. Roller, Roller Ring and Roller Bushing

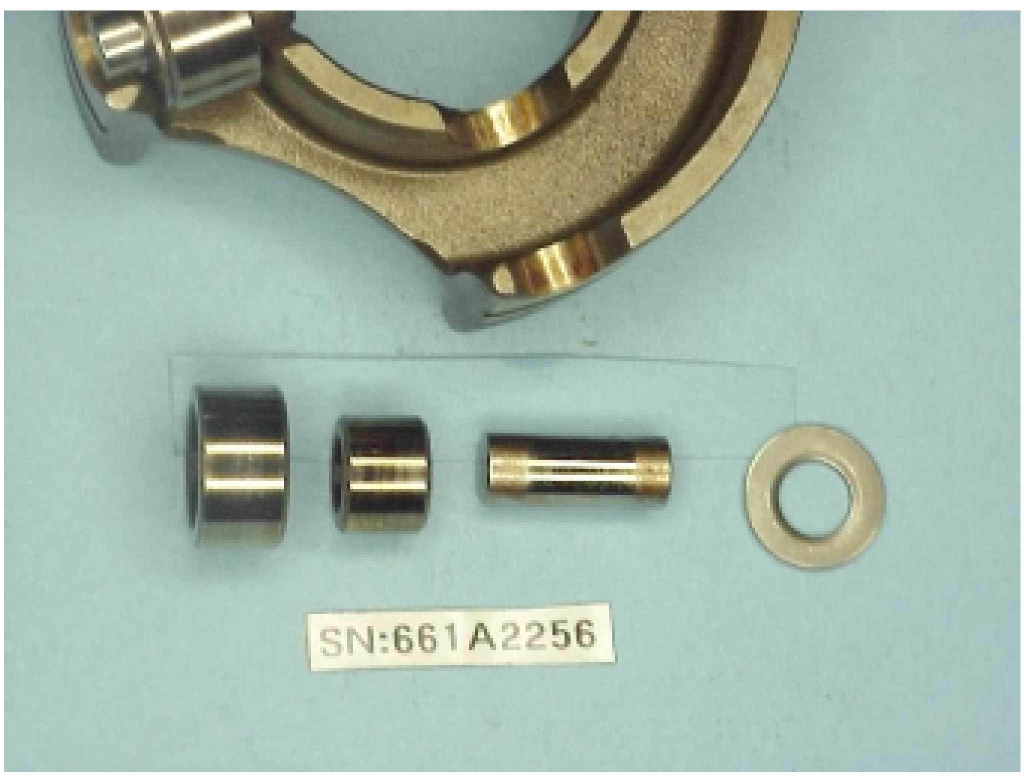

Figure B-6B. Roller, Roller Ring and Roller Bushing

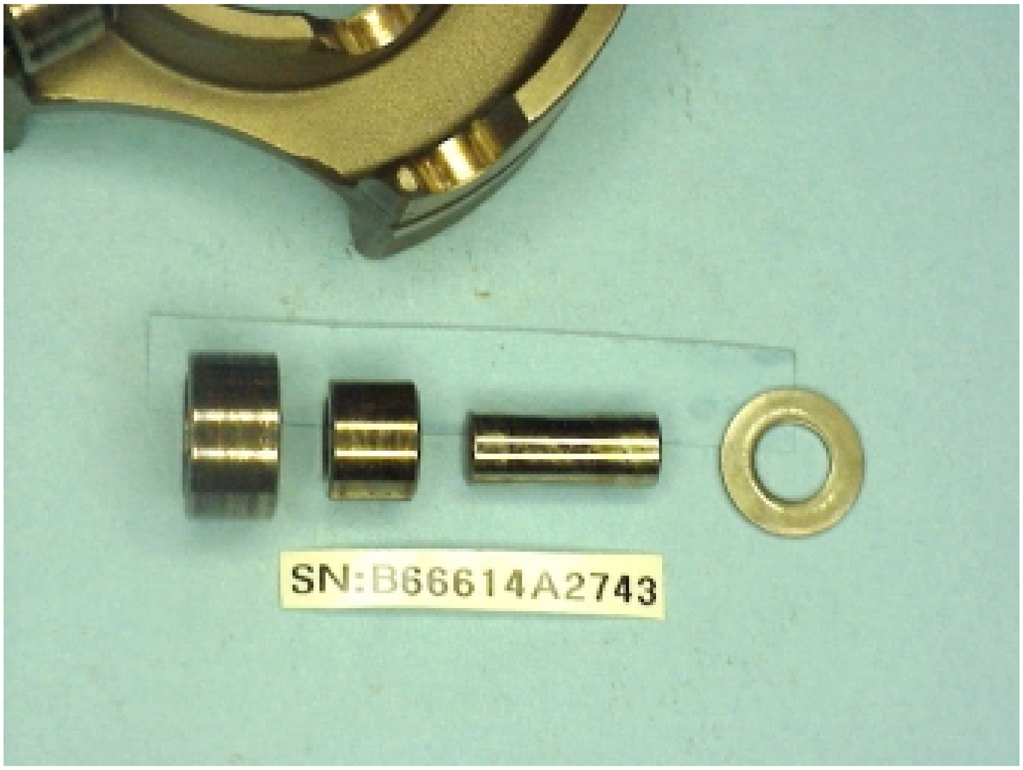

Figure B-6C. Roller, Roller Ring and Roller Bushing

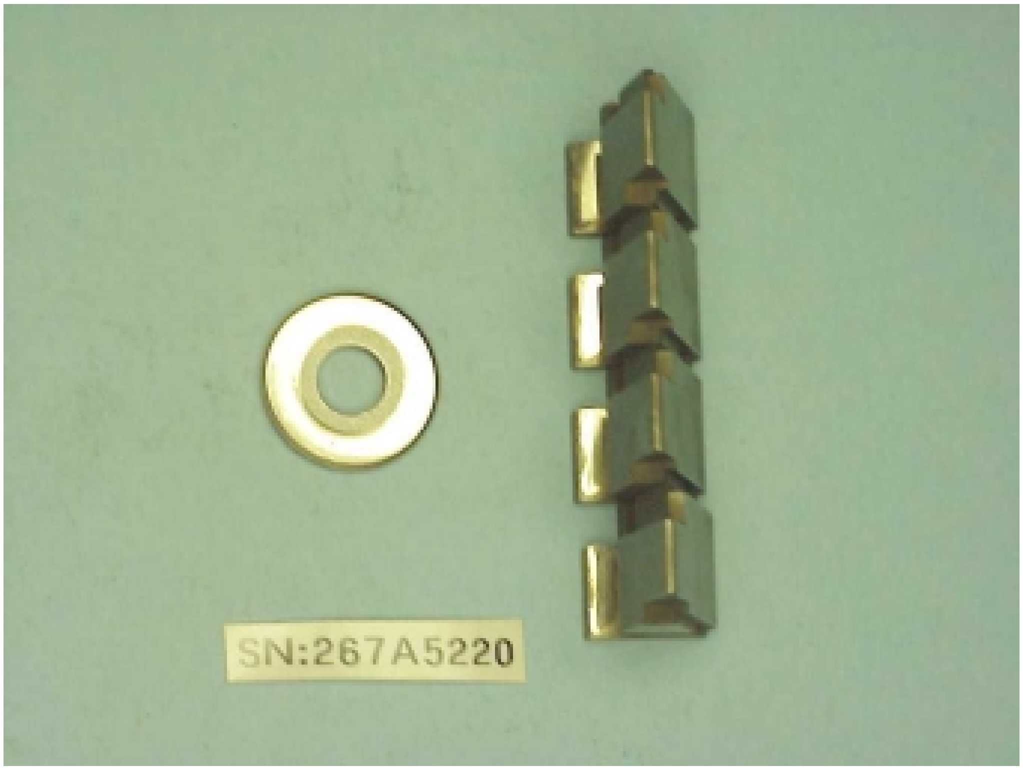

Figure B-7A. Governor flyweights and Butting Ring

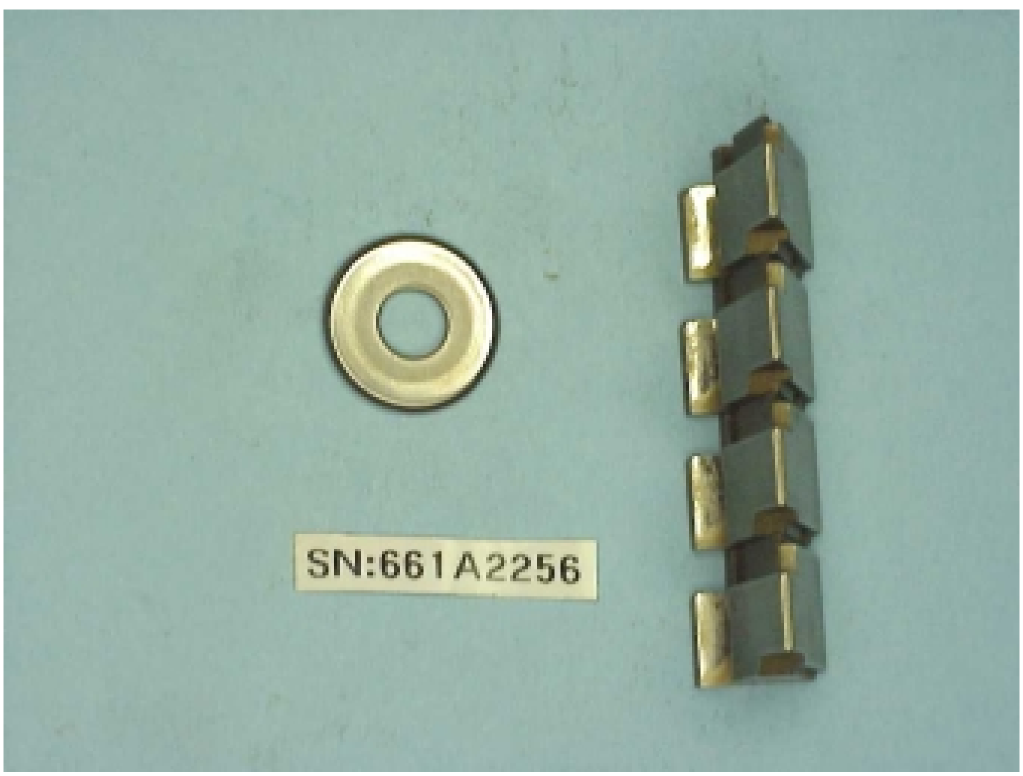

Figure B-7B. Governor flyweights and Butting Ring

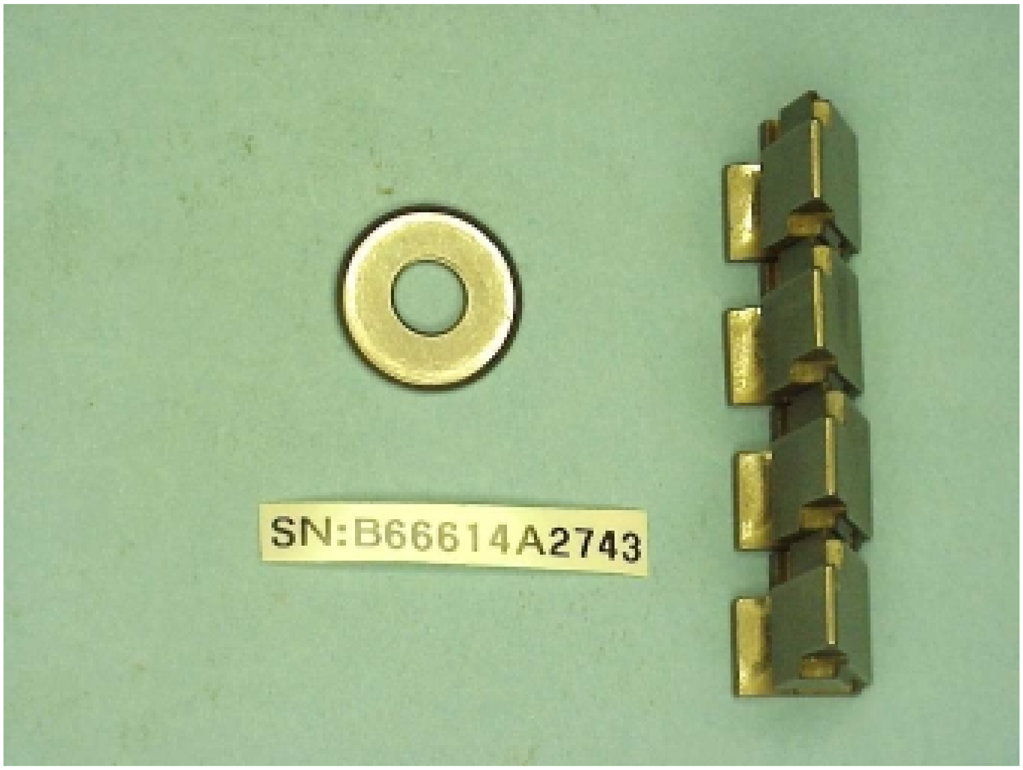

Figure B-7C. Governor flyweights and Butting Ring

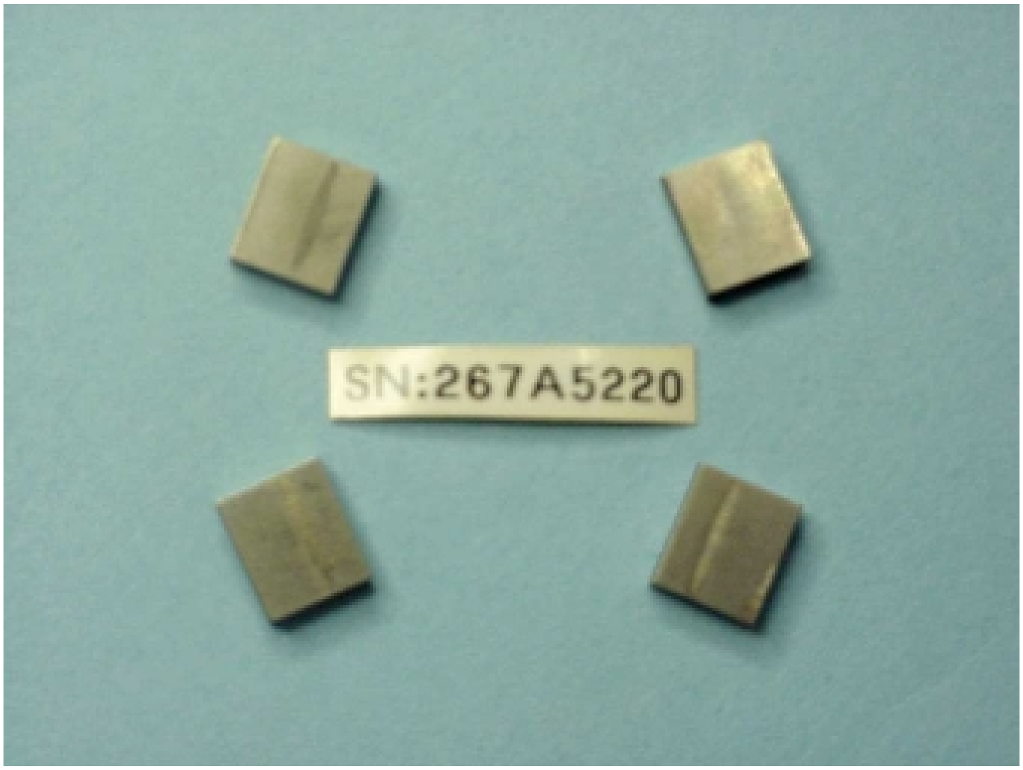

Figure B-8A. Transfer Pump Blades

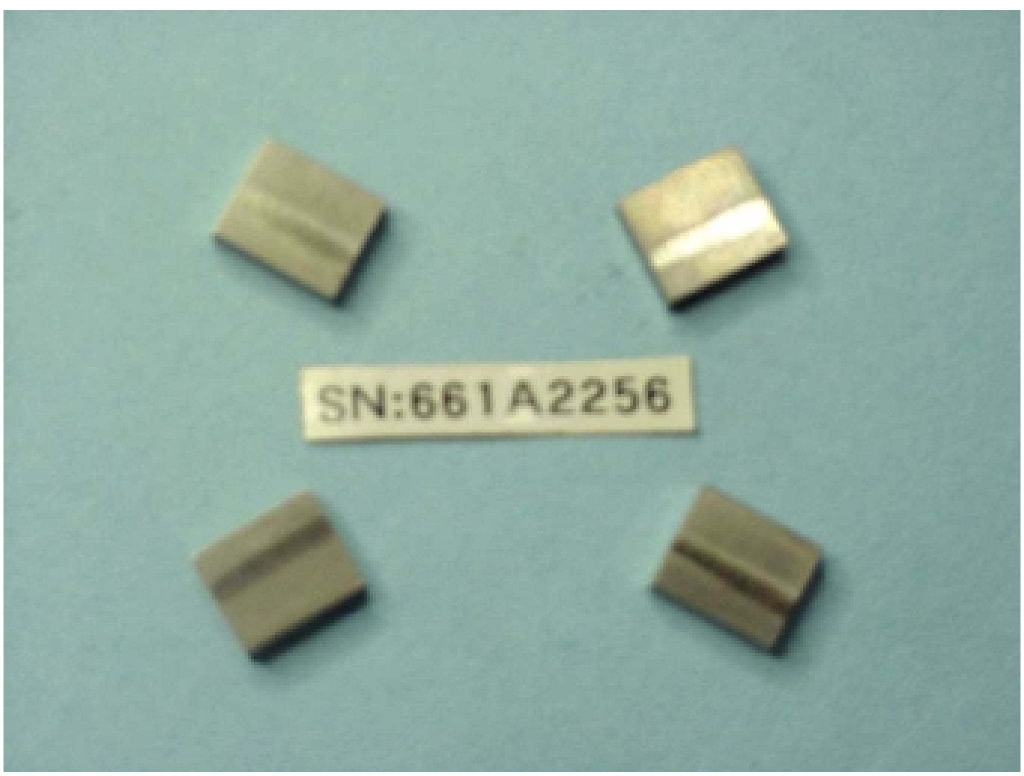

Figure B-8B. Transfer Pump Blades

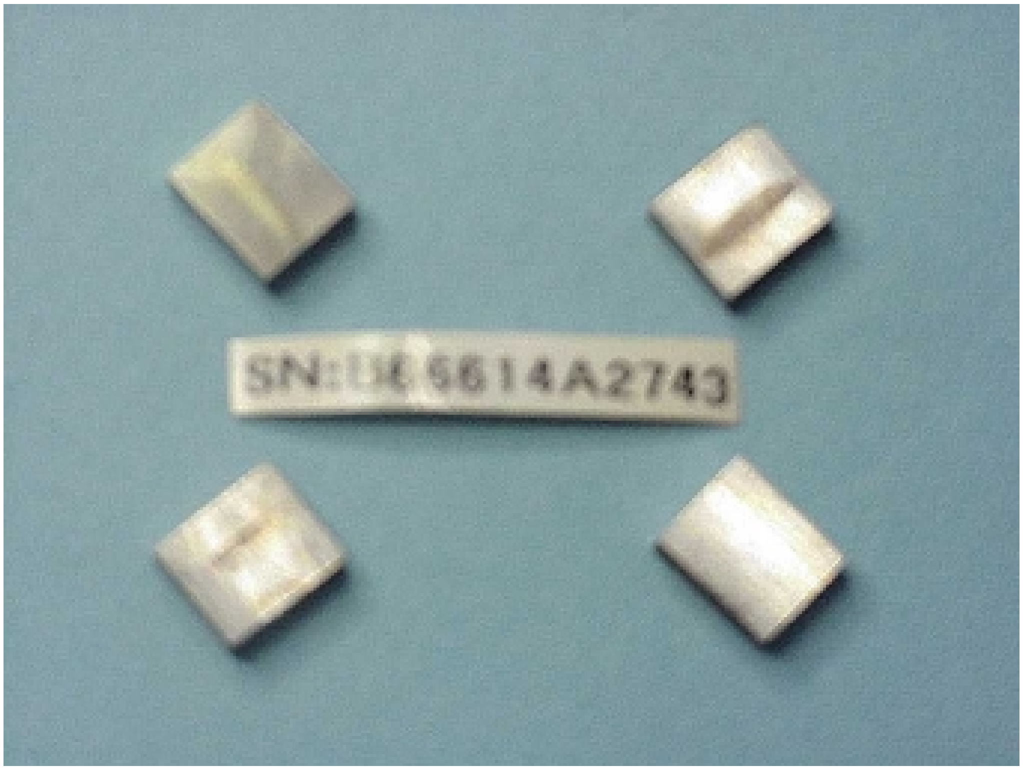

Figure B-8C. Transfer Pump Blades

Figure B-9A. Transfer Pump Liner

Figure B-9B. Transfer Pump Liner

Figure B-9C. Transfer Pump Liner

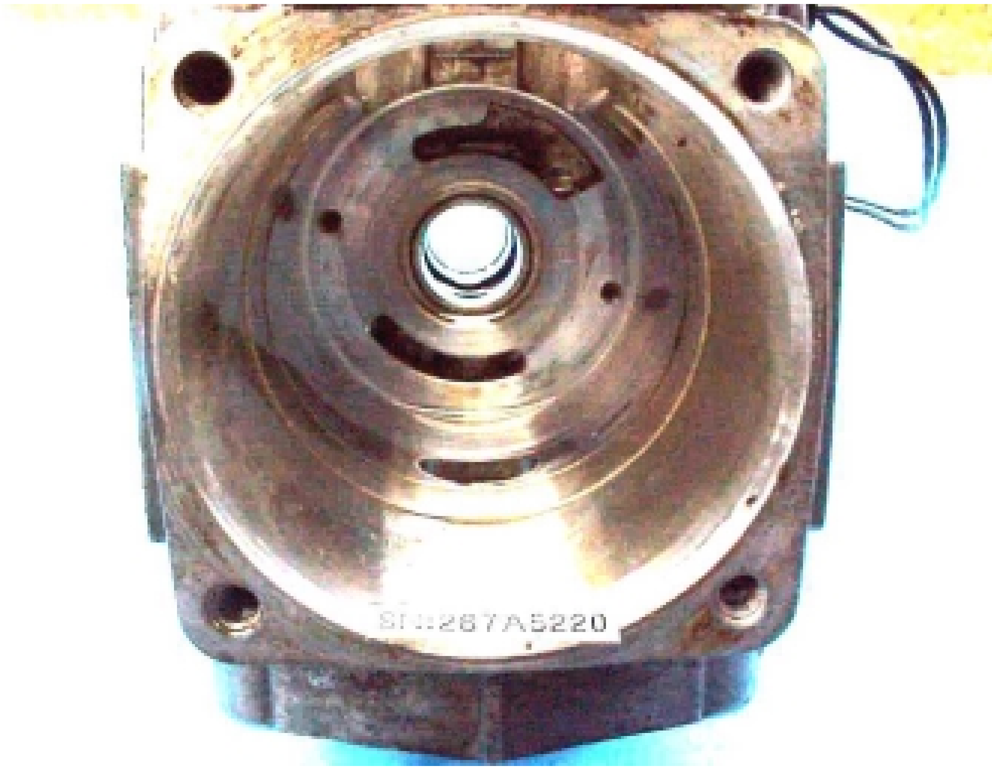

Figure B-10A. Pump Housing

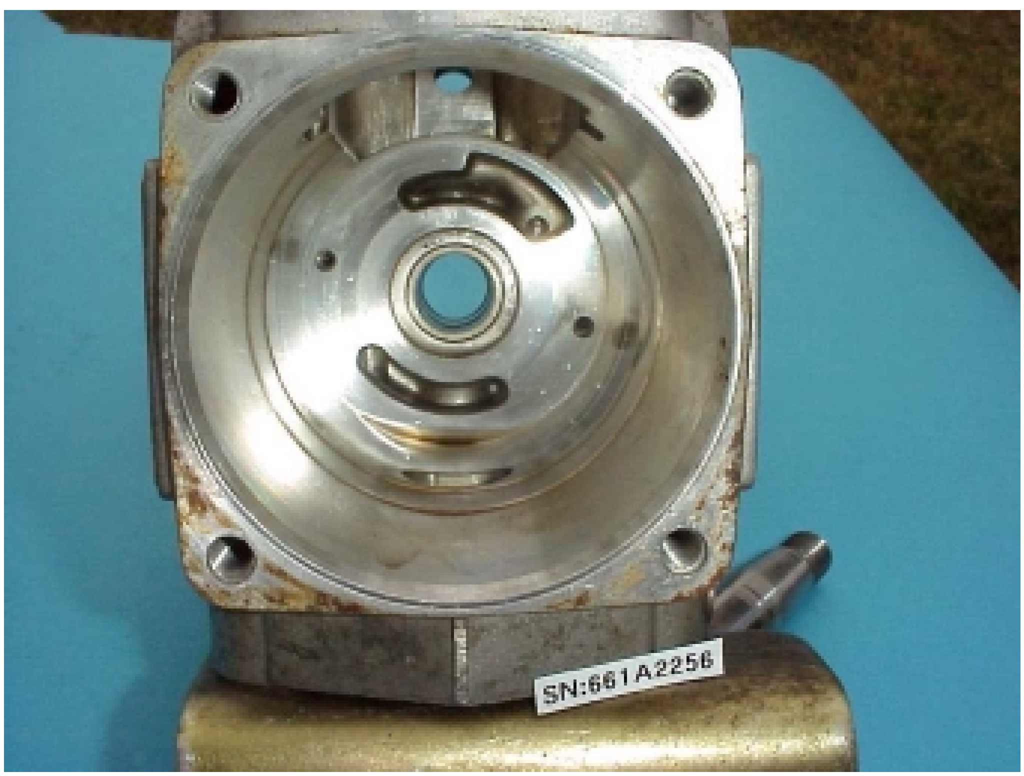

Figure B-10B. Pump Housing

Figure B-10C. Pump Housing